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PROCEEDINGS

of the

Indiana Academy *of* Science

Founded December 29, 1885

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Volume 61
1951

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ALTON A. LINDSEY, EDITOR

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Spring Meeting
May 4-5
McCORMICK'S CREEK STATE PARK

Fall Meeting
November 1-3
BUTLER UNIVERSITY

Published at Indianapolis, Indiana
1952

1. **Instructions for Authors** appear at end of this volume, p. 349.

2. **Exchanges.** Items sent in exchange for the Proceedings and correspondence concerning exchange arrangements should be addressed:

Indiana Academy of Science, Library
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3. **Proceedings** may be purchased through the State Library at $3.00 per volume.

4. **Reprints** of technical papers can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

5. The **Constitution** and by-laws reprinted from v. 44 and the **Membership** list reprinted from v. 61, are available to members upon application to the State Library, Indianapolis, Indiana. **Necrologies** reprinted from various volumes can be supplied relatives and friends of deceased members by the Library.

6. **Officers** whose names and addresses are not known to correspondents may be addressed care the State Library. The address of the editor of the present volume is Dept. of Biological Sciences, Purdue University, Lafayette, Ind.

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Secretary ..... W. A. Daily, Eli Lilly & Company
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Editor ..... A. A. Lindsey, Purdue University
Press Secretary ..... B. Moulton, Butler University

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Chemistry, R. L. Hicks, Franklin College
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Geology and Geography, C. L. Bieber, DePauw University
History of Science, R. E. Girton, Purdue University
Mathematics, Vaclav Hlavaty, Indiana University
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Psychology, George A. Zirkle, Hanover College
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(President, Secretary, Treasurer, Editor, and Chairmen of Junior Academy, Library Program, and Relation of Academy to State)

W. P. Morgan, W. A. Daily, F. J. Welcher, A. A. Lindsey, H. H. Michaud, N. M. Coats, B. Moulton, and F. N. Wallace.

COMMITTEES ELECTED BY THE ACADEMY

Trustees of the Academy Foundation: (term 4 years) Chairman, J S. Wright, Eli Lilly & Co., Indianapolis (term ex. 1952); Ward J. Rice (term ex. 1951).

Bonding of Trustees: (elected annually) Chairman, R. C. Friesner, Butler University; Scott McCoy.

Research Grants: (term 5 years) Chairman, T. G. Yuncker, DePauw U. (term ex. 1954); W. H. Johnson (1952), M. G. Mellon (1955), Paul Weatherwax (1951), J. S. Wright (1953), W. P. Morgan and W. A. Daily (ex officio).

COMMITTEES APPOINTED BY THE PRESIDENT

Auditing: Chairman, K. S. Means, Butler University; S. E. Elliott.

Biological Survey: Chairman, C. B. Heiser, Indiana U.; W. P. Allyn, W. B. Barnes, H. J. Brodie, F. K. Daily, H. O. Deay, S. D. Gerking, H. H. Michaud, Winona Welch, Frank Young.

Index: Chairman, Ray C. Friesner, Butler U.; N. M. Coats, F. N. Wallace, Paul Weatherwax.

Indiana Scientists: Chairman, S. S. Visher, Indiana U.; J. S. Wright, W. E. Edington, M. G. Mellon, Paul Weatherwax.

Indiana Science Talent Search: A sub-committee of the Junior Academy Committee. Chairman, R. W. Lefler, Purdue U.; F. Payne, P. D. Edwards, W. H. Welch, L. H. Baldinger, C. L. Porter, Walter Leckrone (ex officio)

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Membership: Chairman, R. E. Girton, Purdue U.; G. D. Koch, Rev. C. P. P. S. Baechle, Juna Beal, M. G. Mellon, D. E. Miller, S. E. Esten, D. G. Graam, W. H. Headlee, G. F. Hennion, R. L. Hicks, L. B. Howell, B. A. Howlett, C. E. Kaslow, J. L. Hyatt, L. O. Morgan, Zylpha Hurlbut, A. Strickler, M. R. Garner, W. E. Thrun, C. P. Hickman, E. Kintner, M. J. Powell.

Necrologist: W. E. Edington, DePauw University.

Program: Chairman, Benjamin Moulton, Butler University; N. E. Pearson, J. E. Potzger, M. Allen, W. A. Livingston, H. M. Powell, R. E. Esarey.

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Representative on Council of the A.A.A.S.: J. E. Potzger, Butler University.

Resolutions: Chairman, T. G. Yuncker, DePauw U.; Theodore Torrey, P. D. Edwards.

MINUTES OF THE SPRING MEETING

McCormick's Creek State Park, May 4, 5, 1951

President W. P. Morgan called the Budget Committee meeting to order at 5.00 P.M. in Canyon Inn. A budget was presented and approved.

President W. P. Morgan called the Executive Committee meeting to order at 5:30 P.M. in the Canyon Inn. Nineteen members were present.

The officers and committees reported as follows:

Treasurer. W. P. Morgan gave a final report for the year 1950. Treasurer F. Welcher stated that dues cards were still coming in to his office.

Relation of the Academy to State. Nellie Coats reported for Frank N. Wallace stating that the State had appropriated 3,500 dollars a year up to and including 1953 for publication of the Proceedings. No grant was made for the ten year index.

Editor. A. A. Lindsey reported that all the galley proofs will be back from the printer by June for final checking. He hopes to get the reprints cheaper this year.

Index. R. C. Friesner stated that all volumes are indexed with the exception of the one in galley.

Indiana men of science. S. S. Visher reported that the publication would be ready in May.

Library. Nellie Coats reported that the supply of the current Proceedings is very low. 1673 copies are not enough for members and exchange.

Program. Ben Moulton stated that plans for the Fall meeting are well under way.

Research grants. T. G. Yuncker reported that grants have been made to D. Roller and W. Welch. 380 dollars are available for grants.

Representative on Council of A.A.A.S. President Morgan appointed S. S. Visher to find someone to serve as our representative.

New Business. R. N. Harger was appointed to serve out the year of 1951 for J. S. Wright on the Trustees of the Academy Foundation Committee. (Term expires 1952.)

Mason Hufford was appointed to serve out the year of 1951 for J. S. Wright on the Research Grants Committee. (Term expires 1953.)

A motion was made and approved to have the Resolution Committee send a letter of commendation to J. S. Wright in appreciation of his many years of faithful service on the above two committees.

All reports were accepted.

The meeting adjourned at 6:20 P.M.

Dinner Meeting. Following the dinner in Canyon Inn, President Morgan called the short business session to order. After the present officers were introduced to the Academy, Paul Weatherwax presented the distinguished visiting scientist from England, Dr. Julian Huxley.

It was moved and approved that the secretary send letters of well wishes to the following absent members: J. S. Wright, C. C. Deam, Charles Ek, and R. R. Ramsey.

R. E. Girton reported twelve new applicants for membership which were duly elected.

T. G. Yuncker, speaking on behalf of the Resolution Committee wished to thank the management of the McCormick's Creek State Park and Program Committee for a job well done.

Talks on geology and biology of the vicinity were given by J. E. Switzer, R. E. Esarey, T. F. Barton, C. E. Wier, H. H. Michaud and C. B. Heiser, Jr. Kodachromes of some of the fauna and flora were shown by Jack McCormick.

One hundred and twenty-five attended the banquet.

On Saturday morning, May 5, three field trips were organized. These trips and leaders were:

Bird Hike led by H. H. Michaud.

Botany trip by C. B. Heiser, Jr.

Geology trip by R. E. Esarey and T. F. Barton

A luncheon was held in Canyon Inn at 12:30.

One hundred and eighty-seven members and guests signed the roll sheets.

W. A. DAILY,
Secretary

MINUTES OF THE EXECUTIVE COMMITTEE

BUTLER UNIVERSITY, Nov. 1, 1951

The Executive Committee of the 67th session was called to order by Pres. Morgan in Room 311, John W. Atherton Center at 7:30 P.M. The minutes of the Spring Meeting, held at McCormick's Creek State Park were read, corrected and approved. The reports of officers and committee representatives were presented and accepted as follows:

Academy Trustees. In the absence of Chairman Rice, K. S. Means reported as follows for the year 1950-51:

Balance from the previous year	$ 723.96
Total Receipts	339.94
Total	$ 1,063.90
Expenditures	
Transfer to Principal from Income for Investment	$ 500.00
Indiana National Bank fee, 5% on $339.94	17.00
Total	$ 517.00
Cash Balance at Ind. Nat. Bank	$ 546.90

Assets in the Fund as of September 30, 1951

(1)	$5,000 U. S. Savings Bonds Series G-cost	$ 5,000.00
(5)	$1,000 U. S. Savings Bonds Series G-cost	5,000.00
(4)	$500 U. S. Savings Bonds Series G-cost	2,000.00
(4)	$100 U. S. Savings Bonds Series G-cost	400.00
(6)	Shares Standard Oil of Indiana common stock par	150.00
	Total at par or cost	$12,550.00

Treasurer. Tentative report of treasurer, Frank Welcher, for the period beginning Jan. 1 and ending Oct. 31, 1951:

Receipts

Balance on hand January 1, 1951	$1,347.54	
Dues and initiation fees	1,505.00	
A.A.A.S. refund for research grants	175.00	
Designated gifts	625.00	
Author's reprints Vol. No. 55	18.48	
Author's reprints Vol. No. 57	24.04	
Author's reprints Vol. No. 59	225.79	
Publications sold by librarian	15.12	
		$3,935.97

Disbursements

Editorial office	$ 200.00
Expenses of Treasurer	50.19

Expenses of Secretary	71.60	
*Work in preparation of Indiana Scientists		
Bernita Gwaltney	84.00	
Yvonne Hoard	264.60	
*Express for MS of Indiana Scientists	2.68	
Program Committee	119.85	
Research grant—Duane Roller	37.50	
*Furniture for Academy of Science Library	259.60	
Purchase of publications for library	85.33	
Flowers—John S. Wright	15.00	
Returned checks	4.00	
		$1,309.35
†Balance on hand		2,626.62
		$3,935.97

†Balance on hand includes $165.40 in gifts designated for purchase of furniture for Academy of Science Library.
*Paid from funds provided by designated gifts.

(Signed) FRANK WELCHER, Treasurer

(Signed) K. S. MEANS
S. E. ELLIOTT, Auditors

Auditing Committee. K. S. Means reported that the treasurer's report was audited and approved by the committee. The statement of the Indiana National Bank as to the Society's account and holdings was checked by the trustees and the chairman of the auditing committee.

Bonding Committee. Ray C. Friesner, chairman, reported that the bond covering the treasurer and the trustees is in good order. The next expiration date is November 18, 1953, and the bond will be renewed on or before that time unless the Academy should instruct the committee otherwise.

Research Grant. T. G. Yuncker reported that Winona Welch is continuing her study and collection of the moss flora of Indiana with her grant. Duane Roller completed his study of the pre-history of the science of electricity. A grant of $150.00 has been made to Kenneth Wagner to further his study of Indiana bryophytes.

Editor and Publication of Proceedings. A. A. Lindsey reported that Volume 60 of the Proceedings, comprising 350 pages, was published in Indianapolis in September, 1951. In order to avoid rejection of material occupying 70 pages of this volume, it was necessary to substitute a paper binding for the familiar gold stamped black cloth binding. Sixteen hundred copies of the volume were printed, at a cost of $3,036.39. The state appropriation for this volume was $3,000. The difference is to be paid by the Academy fund.

Due to the high bid submitted by the printer of the Proceedings volume for making reprints, a new and less expensive method of making reprints was tried, using photolithography. The reprints resulting

from this offset-printing method appear to be quite as satisfactory as those made by the orthodox printing. Authors were informed in advance of ordering reprints of the exact cost; this had not been possible heretofore. The cost of author's reprints was again borne entirely by the authors at cost. Reprint costs this year are as much as one-third less than last year's price.

Reprints of the instructions to contributors were mailed out to all contributors to the 1951 program; their names were supplied by the divisional chairmen, in advance of the appearance of the printed program.

Press Secretary. Ben Moulton said that press releases were prepared and distributed through two means; the Butler University public relations office and direct release by the Press Secretary. The Academy is indebted to Mr. John Barnett of Butler University for his excellent cooperation and distribution of the news releases.

Greater emphasis should be made upon the regulation that a popular abstract accompany the technical abstract.

Program. Ben Moulton reported completed arrangements of the committee.

Biological Survey. C. B. Heiser submitted the report that new work in the fauna and flora of Indiana has been in the fields of algology, bryology, and entomology. The majority of the papers appeared in the last volume of the Proceedings.

Index. Ways and means of publishing the index Vols. 51-60 as part of Vol. 61 will be discussed at the next meeting of the budget committee. This index will comprise approximately 13,000 entries.

Indiana Scientists. Chairman Visher reported that the volume, Indiana Scientists, is now ready for distribution. It will be sent to all members of the Academy in good standing.

Indiana Science Talent Search Committee. Twenty-three high school seniors were honored at this year's junior scientists assembly and were recommended for scholarships in Indiana Colleges. The junior scientist's assembly will be held in the Riley Room of the Claypool Hotel in Indianapolis on April 5, 1952. Dr. H. J. Mueller, Nobel prize winner, Dept. of Zoology, Indiana University will address the assembly.

It was suggested that the secretary write a letter to Walter Leckrone, editor of the Indianapolis Times, thanking him for his continued loyal support of the Junior Academy.

Junior Academy. Chairman Michaud stated that in 20 years the Junior Academy has maintained a steady response to promoting science activity among high school students in Indiana. Many of the original clubs are still active and new clubs have added to our gradual growth. There are many potential science clubs that need just a little encouragement to take active part in the work of the Academy.

Library. Nellie Coats reported that on a fund supplied by the late John S. Wright, furniture was ordered for the office of the Academy in the State Library Building. In order to complete the furnishing of the room, the Academy will provide an amount not to exceed $600.00.

From the C. A. Behrens estate there was received a file of the Academy's own Proceedings including several scarce issues.

Ninety-seven new titles were added to the list of scientific and technical serials received.

Membership. M. G. Mellon reported for Raymond E. Girton that 32 new applications for membership had been received to date.

Representative on Council of A.A.A.S. W. H. Johnson will represent the Academy at the meeting of the A.A.A.S. this year.

Nominating. Chairman R. C. Friesner recommended that: Ward J. Rice succeed himself as trustee of the Academy Foundation; R. N. Harger complete the unexpired term of the Chairman, John S. Wright; R. C. Friesner, Chairman, and Scott McCoy continue on the Bonding of Trustees Committee; Paul Weatherwax serve another term on the Research Grant Committee; Mason Hufford complete the unexpired term of J. S. Wright on the Research Grant Committee.

New Business. Pres. Morgan appointed a committee of W. A. Daily, chairman; Winona Welch, and Paul Weatherwax to revise the constitution and the duties of the officers of the Indiana Academy of Science.

Another committee was appointed of W. E. Edington, chairman; T. G. Yuncker, and Ray C. Friesner to consider a memorial to John S. Wright.

Messages from the Academy are to be sent to Charles C. Deam and Vice-Pres. J. E. Switzer.

Charles C. Deam was also recognized as a member of fifty consecutive years. The secretary was instructed to write him a letter of congratulations and recognition. Because of his distinguished career as a scientist and his loyalty to the Academy he was made an Honorary Fellow of the Academy.

Soil Science Affiliate—H. P. Ulrich, Pres. of the Soil Science Society of Indiana proposed that they present at the fall meeting a joint program with a related section of the Academy, and that a soils tour be conducted at the Spring Meeting. The proposals were accepted.

The meeting adjourned at 10:00 P.M.

Refreshments were served by wives of members of the Butler University Sigma Xi Society.

MINUTES OF THE GENERAL SESSION

BUTLER UNIVERSITY, NOV. 2, 1951

President M. O. Ross of Butler University welcomed the Academy to the Butler campus. A response was given by President W. P. Morgan.

The minutes of the Executive Committee were read by the secretary and approved by the Academy.

W. E. Edington presented a short biography of each member who had died during the year.

S. S. Visher gave a brief review of the book "Indiana Scientists".

Dr. John E. Potzger presented an excellent illustrated lecture on Isle Royale.

The meeting adjourned at 10:45 A.M. to meet in the various sections.

Luncheon was served to 500 members and guests in the Dining Hall of Atherton Center.

During the annual banquet which was held in Atherton Center, Dr. W. P. Morgan thanked Mrs. Sidney Esten and Mrs. May Iske for the beautiful floral decorations.

R. E. Girton presented the names of 49 applicants for membership. The secretary cast a unanimous ballot in favor of the applicants.

Ray C. Friesner, chairman of the nominating committee presented the names of the following divisional chairmen for 1952: Anthropology, Mrs. George F. Martin, Evansville; Bacteriology, R. C. Bard, Indiana University; Botany, H. R. Youse, DePauw University; Chemistry, E. L. Haenisch, Wabash College; Entomology, F. N. Young, Indiana University; Geology and Geography, T. Barton, Indiana University; History of Science, Duane Roller, Wabash College; Mathematics, E. Hopf, Indiana University; Physics, C. M. Zieman, Wabash College; Psychology, L. M. Baker, Purdue University; Taxonomy, W. Gambill, Jr., Wabash College; Zoology, F. R. Elliott, Valparaiso University.

The following persons were recommended to serve as the 1951 officers: President, P. D. Edwards, Ball State Teacher's College; Vice-President, H. M. Powell, Eli Lilly & Co.; Secretary, W. A. Daily, Eli Lilly & Co.; Treasurer, F. Welcher, Indiana University Adult Education Center; Editor, A. A. Lindsey, Purdue University; Press Secretary, Ben Moulton, Butler University. This recommendation was approved and the officers unanimously elected.

A. A. Lindsey announced that the John M. and Stanley Coulter Prize in Descriptive Botany is awarded to Winona H. Welch for papers published on the mosses of Indiana; and the Charles R. Dryer Prize

in Geography is awarded to Stephen S. Visher for numerous papers dealing with this field.

T. G. Yuncker, chairman, read the following report for the Academy Resolutions Committee: Our Academy has again become deeply indebted to Butler University for their very cordial invitation to hold the 67th annual session on its campus.

The very cordial address of welcome by President Ross was much appreciated.

Especially should we mention the efficient work of the local committee headed by Professor Benjamin Moulton. They provided for all of our meetings in splendid rooms in their beautiful buildings.

We believe that this has been one of our best meetings and our sincere thanks are extended to all the Butler people who have in any way contributed to the comfort and well-being of the Academy members and the success of the meetings.

O. B. Christy announced that the Invitations Committee had accepted the invitation from Valparaiso University, Valparaiso, for the 1952 Fall Meeting of the Academy.

In the absence of the Vice-President, J. E. Switzer, because of illness, the President, W. P. Morgan, was presented by R. C. Friesner. President Morgan delivered a very fine illustrated address on "Those Captivating Irids."

The sixty-seventh annual meeting of the Indiana Academy of Science with a general attendance of 470 and a dinner attendance of 177, was adjourned.

W. A. DAILY, Secretary

NECROLOGY

Will E. Edington, DePauw University

Wilbur Adelman Cogshall

Mendon, Michigan
February 8, 1874

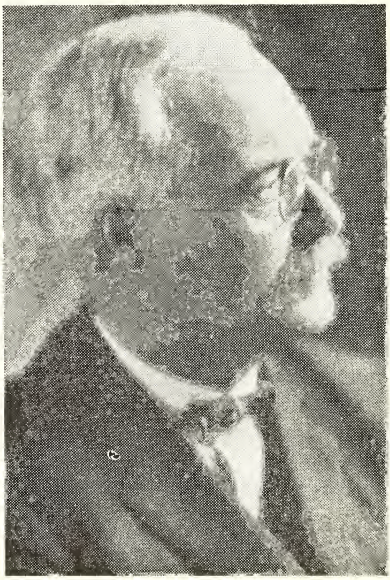
Rockford, Illinois
October 5, 1951

The real history of astronomy in the United States goes back only a little over a century to the founding of the Yale Observatory in 1830. This was followed by the founding of the Harvard Observatory in 1839, the U. S. Naval Observatory in 1840, and the University of Cincinnati Observatory in 1843. During the first half of the last century astronomy was taught in many colleges and universities as a part of a junior or senior course in navigation or natural philosophy. The nineteenth century produced not over a dozen Americans who, during that century, made significant contributions to astronomical knowledge, and one of these was Daniel Kirkwood, (1814-1894), who came to Indiana University in 1856 and remained there thirty years. He was sometimes referred to as "The Kepler of America." Kirkwood Observatory at Indiana University was named in his honor. The first Director of Kirkwood Observatory was John A. Miller, (1859-1946), an Indiana University alumnus, who was Professor of Mathematics and Astronomy at Indiana University from 1894 to 1906. During Dr. Miller's directorship graduate study in astronomy was developed and the first A.M. degree in astronomy granted in 1899. It was three years later before the next two advanced degrees were granted and the recipient of one of these was Wilbur Adelman Cogshall, who had come to Indiana University in 1900 as an instructor in mechanics and astronomy.

Wilbur Adelman Cogshall was born in Mendon, Michigan, on February 8, 1874. Following the completion of his public school education he entered Albion College and received the B.S. degree in 1895. He spent three of the next four years as an Assistant in the Lowell Observatory at Flagstaff, Arizona. In November, 1900, the Board of Trustees of Indiana University appropriated the money for the instrument and the erection of Kirkwood Observatory, and the new building was completed in January, 1901, and the new 12 inch refractor was installed and in use early in February, 1901. Professor Cogshall, who had come to Indiana University in the Fall of 1900, reported on the results of his and Dr. Miller's observations of Mars, at the Fall Meeting of the Academy. He spent the year 1903-1904 as a Fellow at the Yerkes Observatory of the University of Chicago and on his return he was promoted to Assistant Professor of Astronomy. In 1906 Dr.

Miller left Indiana University to become Director of Sproul Observatory at Swarthmore College and Professor Cogshall succeeded him as Director of Kirkwood Observatory. In 1908 he was made Associate Professor of Astronomy and he became a full Professor in 1923. He retired in 1944 after forty-four years of distinctive service to Indiana University.

Following his retirement he went to Rockford, Illinois, as an adviser to an industrial firm in the manufacture of optical equipment for the armed services. In his later years he was a victim of arthritis and he was one of the first arthritis sufferers to be treated with



cortisone. His reaction to this treatment was so remarkable that motion pictures were taken of his progress and shown widely to medical societies. He passed away at Rockford on October 5, 1951.

Professor Cogshall was one of that outstanding group of astronomers including V. M. Slipher, J. C. Duncan, C. O. Lampland and E. C. Slipher, who received advanced degrees in astronomy from Indiana University. Professor Cogshall became nationally known for his work in locating the center of population of the United States. J. A. Miller and he located it first for 1900 and Dr. Miller reported on it to the Academy in 1901. For the next four decades Professor Cogshall located it and he had hoped to help determine it for 1950, but his illness prevented this. As an astronomer he was known chiefly for his work in solar eclipse observations, although he did some work on double stars and comets. He went to Spain in 1906 with J. A. Miller on an eclipse expedition and while in Europe visited a number of observatories. On another expedition he and Mrs. Cogshall went to

the Philippines and they visited certain points in China before returning. He was either a member of or directed a number of eclipse expeditions in the United States, some of which were outstandingly successful and others total failures because of clouds. Probably his most successful work was on the total eclipse of the sun in 1918 which he observed at Brandon, Colorado. Two of his disappointing expeditions were the total eclipse of 1923, when he set up his instruments at Ensenada, California, and the total eclipse of 1932, when he watched the rain fall at Fryburg, Maine, during the eclipse.

Professor Cogshall was a most interesting teacher with a keen sense of humor and a gracious and charming personality. He taught from practical experience and he possessed considerable mechanical ability which was shown in his construction of a reflector telescope which was finally mounted and housed in a building two miles east of Bloomington. He loved to work with students and he was active in the development of the Indiana Union and served on its Board of Directors continuously, except for one year, from the time of its organization until his retirement. For many years he coached the Indiana University cross country team, and he also played on the Faculty team in the annual Senior-Faculty baseball games. He enjoyed association with the young men in his national social fraternity and in 1942 he was presented with the Alpha Tau Omega fifty year membership scroll. One of his principal hobbies was his interest in pedigreed registered boxer dogs.

Professor Cogshall was an active member of the American Astronomical Society. He joined the Indiana Academy of Science in 1905, although he presented a paper in 1901, and he was made a Fellow in 1906. He was President of the Academy for 1915. He served on various Academy committees through the years. He published a number of papers in astronomical journals, and he presented fifteen papers before the Academy of which eight were published in the Proceedings.

ALDEN HERVEY HADLEY

Monrovia, Indiana
August 6, 1876

Anderson, Indiana
February 26, 1951

In the 80's of the last century Indiana was the home of a number of naturalists some of whom were to gain national and international renown. Among these were many whose special interest at one time or another was ornithology, such men as David Starr Jordan, Barton W. Evermann, Willis Blatchley, Stanley Coulter, Amos Butler and Robert W. McBride. The Indiana Audubon Society was founded in 1886 with R. W. McBride as its first president, just a few months after the founding of the Indiana Academy of Science. The conservation of the natural resources of the State became one of the concerns of the Academy, and its early Minutes record numerous Resolutions and Recommendations on bird conservation. It was only natural that interest in bird life should seem important, for the great Audubon had

lived just across the river at Henderson, Kentucky, and his bird studies and paintings included the birds found in Indiana.

About the time of the founding of the Academy a small boy, Alden Hervey Hadley, then only nine years old, became intensely interested in bird life. He was born on a farm in Morgan County, just south of Monrovia, on August 6, 1876. He attended the public schools of Morgan County, and by the time that he was fifteen years old he had obtained a brass telescope, as a prize for securing new subscriptions to the Youth's Companion, with which he studied birds. Graduating from Monrovia high school, he entered Earlham College and came under the influence of David W. Dennis and with him presented a joint paper on "Notes on the Birds observed in the vicinity of Wayne County, Indiana," published in the Proceedings for 1897 under his own name. However, after two years at Earlham his health failed and his family moved to Florida where he entered Stetson University and was graduated. Later he entered the University of Chicago and received a degree there also in 1900. Earlier he had done some study at Guilford College, in North Carolina, and while still in his teens he had spent some time off the coast of Punta Gorda, Florida, on a sponge fishing boat. Later he traveled thousands of miles on bird studies, exploring the Kankakee Swamp in Indiana before its drainage, and spending a number of months in the upper St. John's marshes in Florida and in the Everglades.

Following several years of planning the National Association of Audubon Societies for the Protection of Wild Birds and Animals was founded in 1905, and Mr. Hadley, having definitely become a professional ornithologist, became in time Director of Education of the National Audubon Society in New York. In 1924 he joined the Indiana Department of Conservation but two years later he returned to the National Audubon Society as a traveling representative. He went to Florida in 1935 to organize a program of conservation education and to become an extension lecturer for the University of Florida. In 1941 he returned to Indiana, making Mooresville his home, and joined the State Department of Conservation. During the next ten years he devoted most of his time to traveling over the State giving lectures before public school groups, colleges, universities, luncheon clubs, women's clubs, and garden societies. Since 1941 up until the time of his death in an automobile accident near Anderson, Indiana, on February 26, 1951, he had made a total of 9,385 lectures to 697,649 people. It was not unusual for him to give thirty lectures a week all over the State.

Besides lecturing Mr. Hadley contributed to the Audubon Society Magazine, "American Forests," and others, and at the time of his death he was publishing a series of articles on "Songbirds of Indiana," in "Outdoor Indiana," magazine of the Department of Conservation. He was author of "Permanent Resident Birds of Indiana," a booklet of which more than 75,000 copies have been distributed. While associated with the National Audubon Society he collaborated with Allan Brooks, world famous bird artist, in the preparation of three sets of

cards picturing and describing North American birds, which are still distributed by the Society.

Alden Hervey Hadley had attained national distinction as an ornithologist and without doubt he rendered a tremendous service to the State of Indiana in the furtherance of its conservation program. He had been a member of the Indiana Academy of Science at several different times, first joining in 1897 but allowing his membership to lapse a few years later. He last became a member in 1945 but he had not presented any papers before the Academy in recent years.

At the time of his death the Indianapolis Star printed an editorial concerning him and his work, part of which follows: "Throughout his long career Mr. Hadley, a true spiritual heir of the great James Joseph Audubon, did much to educate public opinion to a proper appreciation of bird life and to the necessity of protecting it. In the death of Alden Hadley the robins and cardinals and wrens and other feathered folk of Indiana have lost a great friend as have many persons who knew this keen and gentle naturalist."

FRED AARON LOEW

Burnips, Michigan — Huntington, Indiana
March 8, 1874 — November 7, 1950

On June 2, 1951, in conjunction with the Commencement program at Huntington College, a marble plaque dedicated to the memory of Fred Aaron Loew was unveiled at the memorial fountain in the Fred A. Loew Botanical Garden and Arboretum on the college campus. This botanical garden had been developed through the vision and efforts of Dr. Loew some sixteen years earlier and was dedicated in June, 1937, and each year since that time a garden program has been held, and will continue to be held, as a definite part of the general Commencement program at Huntington College.

Fred A. Loew was born March 8, 1874, on a farm near Burnips, in Allegan County, Michigan. He completed the work of the grade schools and a village high school, and began teaching in the Dorr and Overisel township schools and attending the normal school at Allegan, the county seat, during the summers. After two years of teaching he attended Hartsville, Indiana, College in 1897-1898, and entered Central College, now Huntington College, in the autumn of 1898. Following his graduation from Huntington College with the B.S. degree in 1902, he entered Michigan State College, receiving the B.S. degree there in 1904 and remaining for another year as an assistant in teaching and in the botanical laboratory, botanical garden and arboretum. Huntington College elected him Professor of Science in 1905 and he spent the next twelve years in that position, during which time he received the M.A. degree from the University of Michigan and also did some graduate study at the University of Chicago, as well as visiting a number of places of botanical interest during the summers.

With the entry of the United States into World War I, he was invited in 1917 to supervise the garden projects in Huntington, and he became Huntington County's first agricultural agent, continuing until 1922. During this time he organized the 4-H work in the county and he maintained an active interest in it until the time of his death. He spent the years 1922 to 1925 as Professor of Biology and Geology at Huntington College and then took up other work, serving as the clerk of the circuit court of Huntington County for the years 1928-1931. After a short period as secretary of a Building and Loan Association he again returned to Huntington College in March, 1932, as Professor of Biology and Director of the Arboretum and Botanical Garden, where he remained until his retirement in March, 1950, on account of ill health. He passed away on November 7, 1950.

Dr. Loew received considerable national recognition because of his work in the development of the Botanical Garden comprised of four acres of various Indiana plants which he had gathered and carefully tended. At one time his Garden contained beds of 593 different weeds and wild plants, many of which had economic and medical use, and many others were ornamental. It was frequently visited by interested people from other states and was of great practical value for instructional purposes.

Fred Loew was primarily a teacher and he was an inspiring teacher who did much for his students. He also believed in an active and close cooperation between the college and the community, and he took an active part in the organization of the Huntington College Foundation. In recognition of his outstanding work Huntington College conferred the honorary Sc. D. degree on him in 1942.

He was a Fellow in the American Association for the Advancement of Science, and he had been active in the Michigan Academy of Science. He first joined the Indiana Academy of Science in 1923 but it was not until after 1935 that be became active in its work. He was elected a Fellow in 1939 and he served on several of its committees during the past few years of his life. He was active in civic affairs, being a member of the Huntington Kiwanis Club and the Chamber of Commerce.

Dr. Loew served his college and his community well and through his efforts future generations of Huntington College students will continue to profit.

ALMA IRENE LONG

Newport, Kentucky — Lafayette, Indiana
July 28, 1883 — September 25, 1951

The Indiana Academy of Science has been fortunate in having a few outstanding women scientists in its membership. One recalls Lillien Jane Martin, Katherine Golden, Cora B. Hennel, Martha Doan and Agnes Wells, several of whom are still living. To this group must be added Alma Irene Long who joined the Academy in 1939 and during the following decade presented seven papers before the Psychology Section.

With her death on September 25, 1951, Purdue University and the Academy both lost one of their most productive workers.

Alma Irene Long's principal research interest was in the psychological aspects of home economics education. She began her career as a teacher of home economics in one of the public high schools in Cincinnati in 1908, and through the years, as she gained varied experience, she became more interested in applied psychology in home economics. She wrote and published a number of research papers in various home economics and psychology journals and she was author of one textbook, "Home Health and Nursing." Shortly before her death she completed her major long-time research study of the social development of the adolescent.

She was born in Newport, Kentucky, on July 28, 1883. Following her graduation from high school it required some time for her to find her major field of scientific interest, for she was almost forty years of age before she received the B.S. degree in 1923 from Teachers College, Columbia University, which was followed by the M.A. degree in 1930. In the meantime she had also done some graduate study at the University of Chicago, and she finally completed the work for the Ph.D. degree in 1933 from Western Reserve University.

In 1909 she began teaching home economics in North Carolina College for Women but with the entry of the United States into World War I in 1917 she went to Washington, D.C., and spent two years in statistical and educational work for the War Industries Board. Following the close of the War she taught home economics at Bradley College for four years and then went to Wittenberg College in 1925 as Head of the Home Economics Department, remaining four years. She then spent a year at Antioch College as head of the nursery school. In 1932 she went to Winthrop College to remain two years as head of the child development training work. During the years 1935 to 1937 she had charge of the adult education in the Putnam School in Grand Rapids. She came to Purdue University in 1938 as Assistant Professor of Home Economics Education and was promoted to Associate Professor in 1943, devoting most of her time to research in the psychological aspects of family life.

Dr. Long was a member of the American Association for the Advancement of Science, and the American Psychological Association, and she was a Fellow of the Educational Research Association, the Midwest Psychological Association, and the Indiana Academy of Science.

Her long experience with and study of children and youth gave her a clear understanding of their problems and a deep sympathy with their behavior and attitudes. She was an invaluable counselor and friend. Moreover she valued friendships highly and she maintained and preserved her friendship with her numerous acquaintances at the various institutions where she had served. Students privileged to work with her were fortunate in receiving her advice and suggestions. Her principal hobbies were sculpture and photography and the Purdue Camera Club awarded her a key in recognition of her services to that organization. Alma Irene Long lived a full and worthwhile life.

LAWRENCE ONIS MORGAN

Turon, Kansas — Bloomington, Indiana
May 22, 1900 — June 12, 1951

With the sudden death of Lawrence Onis Morgan the Indiana University Medical School at Bloomington lost one of its most successful teachers and the medical profession a distinguished anatomist. Dr. Morgan had returned to Indiana only two years before his death.

He was born at Turon, Kansas, on May 22, 1900, and following the award of the A.B. degree at Southwestern College, Winfield, Kansas, in 1922, he came to Indiana University as a part time assistant in embryology and received his M.A. degree in 1923. He immediately went to Cornell University as an instructor in anatomy and neurology and was awarded the Ph.D. degree in Anatomy in 1926. That Fall he went to the University of Illinois College of Medicine as instructor in Histology and Neurology, and three years later he was appointed Assistant Professor of Anatomy in the College of Medicine of the University of Cincinnati. He was promoted to Associate Professor in 1934, and fifteen years later came to the Indiana University School of Medicine at Bloomington as Professor of Anatomy. During World War I Dr. Morgan was in the United States Army for two years.

Dr. Morgan was a member of the Association of Anatomists, the Association for Research in Nervous and Mental Diseases, and the Cincinnati Society of Neurology and Psychiatry. He first joined the Indiana Academy of Science in 1923 but resigned a few years later, and he had only rejoined shortly after his return to the State in 1949.

He was not only an excellent teacher but also a very productive research worker. He was the author of fourteen papers and joint author of seven others published in the leading medical and psychiatry journals. His research was in histology, physiology and anatomy, and in later years in particular the pathological changes in the tuber cinereum and the hypothalamus of the brain in certain diseases and under certain conditions.

Dr. Morgan was not only an excellent scientist, and an inspiring teacher and wise counselor of medical students, but he could be counted on the right side in the spiritual welfare of students. He was an active member and a member of the Board of a Bloomington Methodist Episcopal Church and his two sons were students in Methodist theological seminaries. His untimely death at the age of fifty-one has brought a distinct loss to Indiana University and the State.

BURTON DORR MYERS

Attica, Ohio — Bloomington, Indiana
March 10, 1870 — February 28, 1951

Burton Dorr Myers was one of that group of Indiana doctors and surgeons who made distinct contributions to the medical profession

either in pioneering operation techniques or raising the standards of medical training and education. John S. Bobbs, in 1867, was the first successfully to operate for the removal of gallstones. Livingston Dunlap was a prime organizer of the Indiana Medical Association and the founder of the first hospital in Indianapolis. William H. Wishard pioneered in Indiana in the use of chloroform as an anesthetic, and his son, William Niles Wishard, Sr., was the first to begin the hospital training of nurses in Indianapolis. John Lambert Richmond was probably the first surgeon in the United States to perform successfully, in 1827, the first Caesarean section, saving the mother, and Moses Baker, in 1880, was the first in Indiana to save both mother and child. John N. Hurty pioneered in sanitation and health regulations. Burton D. Myers was one of that group that insisted on high educational standards for the medical profession and the outlawing of medical "diploma mills."

Burton D. Myers was born on March 10, 1870, in Athens, Ohio. After completing the work of the public schools he entered Buchtel College, now the University of Akron, from which he received the Ph.B. degree in 1893. He spent the next four years as the superintendent of the high school at Greenwich, Ohio. In 1898 he became an assistant in physiology at Cornell University and received the A.M. degree in 1900. He then went to Germany for further training, particularly in anatomy, where the M.D. degree was conferred on him in 1902 by the University of Leipsig. The following year was spent as an Assistant in Anatomy at Johns Hopkins University and in 1903 he was called to Indiana University as Professor of Anatomy. In 1920 he was appointed Assistant Dean of the Indiana University Medical School at Bloomington and he became Dean in 1927. He retired in 1940 as Emeritus Professor and Dean, having completed thirty-seven years of outstanding service to the University.

Dean Myers was recognized as a vigorous and excellent administrator with both vision and foresight, who gained and held the respect, confidence and support of his colleagues. He was deeply interested and active in civic affairs, having served as president of both the Bloomington Chamber of Commerce and the Monroe County Tuberculosis Association. A charter member and past president of the Bloomington Kiwanis Club, he was at one time a Trustee of the Kiwanis International and in 1923 the District Governor for the Indiana District. He was active in the Kiwanis State campaign to secure funds for the construction of the Kiwanis wing of the James Whitcomb Riley Hospital for Children in Indianapolis. At one time he was vice-chairman of the Indiana State Planning Board. He was also active in the Bloomington First Methodist Church and sang in its choir.

Dr. Myers was a member of the American Association of Anatomists and the American Medical Association, and a past president of the Association of American Medical Colleges. He also held membership in Sigma Xi, Phi Beta Kappa and Alpha Omega Alpha, the latter an honor society in medicine. He was also a Fellow of the American Association for the Advancement of Science. He joined the Indiana Academy of Science in 1911 and was elected a Fellow in 1936.

While primarily an administrator, he nevertheless published papers in medical journals, and he occasionally was active in the Academy but he published only one paper in the Proceedings. Following his retirement he devoted his time to the research, writing and publishing of two historical works: "History of Medical Education in Indiana," and "History of Indiana University, 1902-1937."

Dean Myers passed away suddenly on February 28, 1951, leaving behind him a long, rich, full life of service to mankind, and service in particular to the thousands of Indiana University medical students in whom he helped to inculcate the high ideals and ethics of the medical profession.

EDWARD CLEMENT STAIR

Brook, Indiana — West Lafayette, Indiana
November 7, 1889 — September 8, 1951

With the death of Edward C. Stair on September 8, 1951, Purdue University lost one of its widely known professors, for he had been active for years as a judge of fruit and vegetable shows at county fairs all over the State. He was also active in community and church affairs, being president of the Tippecanoe Council of Churches and president of the Official Board of West Lafayette First Methodist Church at the time of his death. He had been president of the Lafayette Lions Club in 1949-50, and he was also an active Mason.

Edward Clement Stair was born near Brook, Indiana, on November 7, 1889. He graduated from Brook High School in 1910 and immediately entered Purdue to study agriculture. He received the B.S. degree in agriculture in 1914, and later, in 1925, the M. S. degree. He spent the year 1936-37 in graduate study at Cornell University.

Following his graduation from Purdue he taught vocational agriculture in Arsenal Technical High School in Indianapolis for three years and then filled a similar position in Union Township High School, Johnson County, for another three years. He returned to Brook in 1920 and farmed for three years. In 1923 he became an instructor in horticulture at Purdue and was promoted to Assistant Professor of Horticulture in Vegetable Gardening in 1931. He became Associate Professor in 1936.

Professor Stair was a member of the American Association for the Advancement of Science, the National Vegetable Growers Association, the Indiana State Horticultural Society, and the Indiana State Vegetable Growers Association. He was a Fellow of the Society of Horticulture Science. He became a member of the Indiana Academy of Science in 1924.

He was interested in plant breeding and greenhouse management, and for fifteen years he was Faculty Sponsor of the Horticultural Show and the Purdue Horticultural Society. The Thirty-eighth Annual Purdue Horticultural Show, held November 2-4, 1951, was dedicated as a memorial to Professor Stair.

Edward Clement Stair was an influential teacher and a splendid citizen who devoted twenty-eight years of his life to useful service to Purdue, to his community and to the State.

WALTER EUGENE THRUN

Bloomfield, Wisconsin — Valparaiso, Indiana
March 22, 1892 — August 19, 1951

During the twelve year interval 1934 to 1945, inclusive, American universities awarded 8,958 Ph.D. degrees in the five fields of Botany, Chemistry, Mathematics, Physics and Zoology. Of these 5,027 were in Chemistry, so that more Ph.D.'s were awarded in chemistry than in the other four subjects combined. Consequently to become distinguished in chemistry appears to be more difficult than in many other fields, so far as numerical competition is concerned. However, Walter E. Thrun, Professor of Chemistry for twenty-two years at Valparaiso University, devised a new method for determining the flouride content in water which reduced both the amount of water and the time required for the test by 90 per cent, as compared to previous standard methods, and his test could be made in the field. Requests for reprints of his article, "Rapid Methods for Determining Fluoride in Waters," came from colleges and laboratories all over the world. This article also described a rapid method by distilling the water. Also he had done outstanding research in methods for spot testing for aluminum and iron. He contributed to such journals as "Industrial and Engineering Chemistry," "Analytical Chemistry", "Journal of Home Economics", "Iron Age", "Journal of Chemical Education" and others. A thorough and patient teacher, he had a passionate zeal for original research, and had directed a large number of his students into careers in applied and industrial chemistry.

Walter Eugene Thrun was born on March 22, 1892, at Bloomfield, Wisconsin. After graduation from high school he first entered Northwestern College at Watertown, Wisconsin, but later transferred to the University of Michigan where he received the A.B. degree in 1912 and the M.S. degree in 1914. He immediately went to the University of Missouri as a graduate student and assistant in chemistry in the Experiment Station and received the Ph.D. degree in 1917. He then began work at the University of Illinois as an instructor in physical chemistry but soon was called into the United States Army, Division of Chemical Warfare and Division of Nutritional Service. While still in the Army he spent a year at Johns Hopkins University as a Fellow in the School of Hygiene and Public Health. In the Fall of 1919 he went to Baylor University as Professor of Chemistry in the Medical College, and the following year to the Mississippi Agricultural and Mechanical College as an Associate Professor of Chemistry. In 1923 he went to the University of Louisville as Assistant Professor of Chemistry for one year, and the next two years he spent as an instructor and Columbia Carbon Fellow at Lehigh University, after which he became a chemist in the Experiment Station of Michigan State College. Following his appoint-

ment as Assistant Professor of Chemistry at Valparaiso University in 1929, he was promoted to Associate Professor in 1931, Head of the Department in 1932, and Professor in 1939.

Dr. Thrun was a member of the American Association for the Advancement of Science and the American Chemical Society, and a Fellow of the Institute of Chemistry. He was also a member of Sigma Xi. He joined the Indiana Academy of Science in 1938 but he was not well known to many members of the Academy.

He was an able and effective teacher and was deeply interested in and helpful to students genuinely interested in chemistry. He was sincere, humble and honest in his efforts and he held a plain, happy philosophy of life. A great lover of horses he possessed several of them and he knew a great deal about them.

In the death of Dr. Thrun at the comparatively early age of 59, while still at the height of his productive powers, Valparaiso University and the State have lost a man who brought distinction to both through his outstanding service.

HARRY AUGUSTUS WASHBURN

Waldron, Indiana
September 4, 1873

Waldron, Indiana
April 24, 1950

Dr. Harry Augustus Washburn had a wide acquaintance with the older medical doctors of Central Indiana and Central Eastern Illinois for, until his retirement in 1939, he had traveled regularly for many years over this area as a representative of The Central Pharmacal Company of Seymour, Indiana.

Dr. Washburn was born at Waldron, Indiana, on September 4, 1873, the son of a physician. After completing the work of the Waldron public schools, he entered Purdue University and later transferred to Indianapolis where he completed the work in the Indiana University Medical School in 1897 for the M.D. degree. He practiced medicine for eleven years at Freetown and Valonia, in Jackson County, and he served as County Coroner at one time. In 1908 he joined the Central Pharmacal Company, which he served as vice-president and president, as well as traveling representative. He retired from active service with the Company in 1939 but he remained a director up until the time of his death at Waldron on April 24, 1950.

For many years, as a hobby, he collected coins, postage stamps, Indian relics and antiques. A few years ago he sold his extensive collection of Indian arrow heads, axe heads, knives, etc., to a prominent Indiana anthropologist. His home was filled with beautiful antiques and he became an authority in this field and much of his time after his retirement was devoted to this work.

He was deeply interested in and generous in his support of civic, church and lodge projects in Waldron. He was an active member of the Methodist Church and a member of the Modern Woodmen and the Knights of Pythias. Also he was active in all bodies of the York Rite

and Scottish Rite Masonry and a member of the Murat Shrine of Indianapolis.

Although in ill health in his later years he maintained an active interest in many different pursuits. He joined the Indiana Academy of Science in 1935, being especially interested in the work of the Archaeology and Anthropology Section.

Dr. Washburn was a man of wide and varied interests with a keen understanding of human nature. He enjoyed the admiration and respect of his friends and business associates because of his many sterling qualities.

IRA TEMPLIN WILSON

Jonesboro, Indiana — Toledo, Ohio
January 29, 1895 — June 11, 1951

One of the most active members of the Academy of Science as a non-resident of Indiana was Dr. Ira Templin Wilson, Professor and Head of the Biology Department of Heidelberg College since 1923 and a member of the Academy since 1919. During the past ten years he had been closely associated with Dr. John E. Potzger, of Butler University, in several lake sedimentation studies and they published jointly several papers. At the time of his death on June 11, 1951, he left several unfinished articles on his more recent researches.

Ira T. Wilson was born at Jonesboro, Indiana, on January 29, 1895, and he received all his formal education in the State, being awarded the A.B. degree at Indiana University in 1919, the A.M. in 1921, and the Ph.D. in Zoology in 1923. Following his graduation from high school, he taught two years in high school to help pay his way through the University, since it was necessary for him to earn his way. His entire professional career was spent at Heidelberg College, in Tiffin, Ohio. He was an outstanding teacher and leader among the Faculty, and he was responsible for not only developing a strong biology department but also for advocating many professional advances and insisting on high college standards in general. He had an active and influential part in planning and establishing Heidelberg College's present student health service, and for a number of years he represented the college in the Ohio Athletic Conference. He was one of Tiffin's leading citizens and he served on the Tiffin Board of Health where he initiated many of the advances in public health codes and standards for the community. During World War II he was active in Civil Defense work and he gave considerable time to teaching first aid classes. He was a member of the Tiffin Lions Club.

Dr. Wilson was especially active in research during the summers. He spent three summers as an instructor at Winona Institute and nine summers at the Indiana University Biological Station. He was also on Indiana University's Extension staff from 1925 to 1940. During the past twelve years he conducted research projects under the sponsorship of the Ohio Department of Conservation, the Michigan Institute of

Fisheries, the University of Michigan, and the Great Lakes Research Institute. His principal research field was limnology or the study of the formation and sedimentation of fresh water lakes and ponds. He was a pioneer in this field to the extent that he had to develop many of the techniques and design his own core sampling equipment, both of which are now widely used in this work. "Perhaps his most remarkable scientific contribution was the discovery of a 'time table of the ages,' a method of determining geological periods with exactitude by examining layers of sedimentation." He published a number of articles, either alone or jointly, in the "Journal of the American Society of Limnology and Oceanography", the "Journal of Sedimentary Petrology", the "American Midland Naturalist" and others. Several of his papers and a joint paper with Dr. Potzger were published in the Proceedings of the Academy.

He was a member of the American Association for the Advancement of Science and the American Society of Zoologists. In 1948 he was vice-president of the Society of Limnology and Oceanography. He was a Fellow of the Ohio Academy of Science and a member of the Michigan Academy of Science. He also held membership in Sigma Xi and the American Association of University Professors.

Ira T. Wilson was a long time sufferer from heart trouble and in his later years he was never permitted to enjoy a sound, undisturbed sleep, and at times it was necessary for him to sleep "propped up." But despite this handicap that would have discouraged a weaker man, he carried on. He possessed a remarkable optimism and a keen sense of wit and humor that served admirably to illustrate a point in the class room or to resolve a difficulty in a tense situation. He had the ability to analyze a problem or situation and the wisdom to suggest a solution. An enthusiastic teacher, he inspired his students with a love for scientific investigation and a great number of them have distinguished themselves in teaching, research, medicine, public health, and conservation. He has left an indelible mark on Heidelberg College and future generations will recognize and honor him as one of its great teachers.

JOHN SHEPARD WRIGHT

Clermont, Indiana
October 17, 1870

Indianapolis, Indiana
July 11, 1951

The announcement of the death of John S. Wright on July 11, 1951, was received with real sorrow and the keenest regret by those many members of the Academy with whom he had worked throughout the years. For them he represented the tie with the "Giants of Other Days," for he knew them all and he had actively served the Academy longer than any other member in its history. Physically active and mentally alert to the end he had served the Academy for fifty-seven years, and he had seen and approved some of the page proofs of "Indiana Scientists" just a short time before his death, which occurred after a brief illness.

He was born at Clermont, Indiana, on October 17, 1870. Following the usual public school training he entered Purdue University and was graduated with the B.S. degree in 1892. A few days after graduation, on June 13, 1892, he entered the employ of the Eli Lilly Company as a botanist and he remained and grew with that great organization, becoming Director of Advertising in 1904, a member of the Board of Directors in 1927, and Advertising Consultant in 1937. He retired from active duty in 1943 but he remained on the Board of Directors until April, 1951.

He joined both the American Association for the Advancement of Science and the Indiana Academy of Science in 1893, and was made a Fellow in the Academy in 1894 and in the Association in 1899. While active as a botanist he wrote and published a number of papers on medical botany, histology of drugs and foods, and pharmacology of plant drugs. As time went on he became active in conservation and wrote papers on forestry. In 1895 he became Secretary of the Academy and served in this capacity for ten years, under the presidencies of Amos Butler, Stanley Coulter, Thomas Gray, C. A. Waldo, Carl Eigenmann, David W. Dennis, Mason B. Thomas, Harvey W. Wiley, Willis S. Blatchley and Carl L. Mees, probably as outstanding a group as ever headed a state organization. In 1905 he became President of the Academy. Throughout the following years he served continuously on committees, much of the time on several committees simultaneously, such as the Committee on Relation of Academy to State, Research Com-

mittee, Research Grant Committee, Endowment Committee since 1929, and Trustee of the Academy Foundation since 1931, as well as special temporary committees.

In his later years, particularly after his retirement from active service with the Eli Lilly Company, he became interested in the History of Science and he presented and published several papers. Much of this interest developed through his active participation in the Academy's Fiftieth Anniversary Meeting in 1934 and the American Association for the Advancement of Science Meeting in Indianapolis in 1937. This interest led to his advocating the publication of a historical Directory of Science for Indiana which resulted in the recent volume, "Indiana Scientists", for which he personally financed much of the preparatory expense, and as a Director of the Lilly Endowment, he made financial arrangements for its final publication.

Another of his special interests was the Academy Foundation Fund, of which he was a Trustee for the past twenty years, the Fund increasing from $4,192 in 1931 to $12,050 in 1950, due largely to his wise counsel and personal efforts.

In 1940 Purdue conferred the honorary LL.D. degree on him and in 1942 he was one of seventeen "golden graduates," members of his class of 1892, to receive Golden Certificates from the University. Also the Academy at its Banquet Meeting in 1945 paid special tribute to Dr. Wright and Dr. Foley in recognition of their long and valuable service to the Academy.

Dr. Wright was a member of the Indiana Historical Society, Indiana Pioneers, Indianapolis Century Club, Indianapolis Literary Club, Columbia Club, Indianapolis Athletic Club, and Meridian Hills Country Club. Following his retirement in 1943, he became active in the Marion County and Indianapolis Tuberculosis Associations, the Indianapolis Family Service Association and the Indianapolis Community Chest. He was a member of the Board of Trustees of Meridian Street Methodist Church.

John Shepard Wright was a quiet, scholarly man devoted to the highest ideals and possessed of the courage, determination and persistence to work for the attainment of those ideals. Recognized as a leader for his wisdom and integrity, he was also a gentle and kindly man devoted to his friends. He has left an imperishable mark on the Indiana Academy of Science and he will henceforth take his rightful place as one of the "Giants of Other Days."

PRESIDENTIAL ADDRESS

Those Captivating Irids

W. P. Morgan, Indiana Central College

An examination of the subjects covered by former presidents indicates that I am not setting a precedent by presenting material drawn from my avocation. This avocation had so many interesting features that at times it threatened to become my vocational classification. Although my professional assignments have been continuously in the field of Zoology most of my spare time since 1926 has been spent in the field of plant breeding. Many problems in plant genetics have been encountered, some have been reported in publication, but these items have largely been considered the tools in production and not the end product. It is the end product that spells success in plant breeding, especially when that product has commercial value and is produced at considerable cost. It is obvious that information that would be used directly by competitors would not be published. Unless plant breeding is restricted to the status of a mere hobby, certain conditions must exist: (1) there must be facilities for work and production; (2) the breeder must know the medium (genera, species, varieties) which must be responsive to the techniques available; (3) there must either be an established market or opportunity for establishing one; and (4) there must be acceptable publicity. These are major items required in a successful plant breeding program, however minor items not mentioned may arise and become of major importance in special cases.

My own work has been mainly with Iridaceae, whose ancestors were natives of South Africa; namely, the genera Freesia and Gladiolus. Both these genera are quite variable and beautiful; brightly colored hybrids have been produced and used in Europe and America for nearly a century. Both produce corms which are solid and lack the concentric scales found in the true bulbs, such as onions, lilies, tulips, etc. However, it is the general practice among growers to call the corms bulbs, and this I have done. Facilities in addition to those present in the college laboratories have been quite adequate. This has been due to the location of a large commercial greenhouse establishment near the college campus and the interest and experience of its owners[1] in the introduction to the florist trade of new varieties of flowers. As previously published, I immediately fell heir to a small stock of freesia seedlings, largely nondescript and of unknown parentage, except that the original stock had been commercial varieties purchased several years earlier. They had not been subjected to the usual culling because there was a demand for freesia blossoms in bunches of mixed colors. This was

[1] Len S. Elder and W. Russell Elder of Elder Brothers, Inc., Indianapolis, Indiana.

fortunate because here had accumulated a veritable reservoir of plant breeding material. Thus it was not necessary to begin from scratch.

One outstanding white seedling had been selected from the lot and its bulb stock increased sufficiently to demonstrate its merits as a commercial form. White freesias were in greatest demand as florists cut flowers and the new seedling was better than any white variety available. At that time an improved form of the old Refracta Alba, known as Purity, was being grown in California in large quantity for the florists of America and Europe. This new variety, named Elder's

Fig. 1. Commercial variety "Giant White" with Freesia species *Hurlingii* which was pictured in the Botanical Register of 1816.

Fig. 2. Golden-yellow "double" variety "Judy".

Fig. 3. White "double" showing many petals.

Giant White (Fig. 1), was granted plant patent number 17. Its commercial possibilities seemed attractive enough to induce these greenhouse owners to launch a new enterprise devoted to the large scale production of bulbs to be sold through dealers to florists for forcing in greenhouses for the cut flower trade. Freesias from field grown bulbs

are blossomed in cool greenhouses similar to and often with carnations. Florists usually found it more profitable to purchase new stock each year rather than use their valuable greenhouse space in maturing the forced bulbs. This was an established market with which these owners were quite familiar. Such an enterprise required considerable faith, energy and financial investment, since greenhouse maintenance for the breeding program was costly and a suitable location for field production had to be established. This last item was an entirely new undertaking and especially difficult when one considers the fact that the parties to the decisions were two florists and a professor of Zoology, all throughly Hoosiers by birth and residence. The three possible locations were Florida, Rio Grande Valley of Texas, and the coastal region of southern California. The studying of weather records, visiting locations and checking conflicting statements and advice were certainly confusing. One decision remained unchanged: to directly control the field growing of our bulb stock and not submit to the offers of established growers to produce our varieties on a contract basis. After one year of unsatisfactory climatic conditions in Florida, field culture was removed to California, first to Solano Beach and later to the vicinity of Oceanside. The peak area under intensive cultivation was ten acres. The accompanying illustration (Fig. 4) shows a part of this planting devoted

Fig. 4. A planting of "Giant White" near Oceanside, California, illustrating the field production of Freesia bulbs.

entirely to the variety Giant White. The greenhouse space for this work reached a peak total of five 100 foot houses which in later years was reduced to two houses and finally to one narrow 100 foot house. A part of the greenhouse space was taken up with an assemblage of all obtainable freesia varieties. One or more pots of each named variety, which at one time numbered over one hundred, was grown in order that direct comparisons could be made, and they also served as a source of breeding material. These were obtained from sources in America, England and Holland. In addition more than fifty species of bulbous plants of South African origin were grown for breeding or observation. Several of these, some not Irids, were introduced and continue to be grown by American florists.

Extensive flower exhibits were made at the National and International Flower shows in America and especially arranged exhibits were made in London, England; Haarlem, Holland; Cannes and Nice, France and Florence, Italy. These exhibits with the extensive descriptive material about our giant-flowered colored varieties published in popular and trade magazines resulted in our freesias being well received and their use by florists increased.

The above has largely been a statement of how a professor in a small college located in Indiana could have the needed extensive facilities for carrying on a program with plants largely of South African origin. My part in the program was to produce new varieties whose bulbs were then grown in quantity in California and distributed to florists for the production of cut flowers. In this work the hybridizing by hand pollination was done during the blooming season which ranged from January through April. This resulted in thousands of pedigreed seed each year from several hundred planned crosses. Seed harvested during the summer was planted in flats the following fall and produced bulbs that were planted on the greenhouse benches. These were ready for check and selection or destruction during their second season following the planting as seed. Where selections were made for further observation, these were grown until the stock of bulbs reached a quantity large enough to require final judgment of: (1) destruction, (2) limited introduction to the private estates as novelties or (3) sent to California for further increase preparatory to commercial introduction. We planned to introduce only a limited number of varieties of sufficient merit to replace those being offered by competitors, therefore a final recheck by flowering in the greenhouse of the field produced bulbs was a necessary precaution. At times this required rather hard-hearted actions. As an example of this, one variety had reached the 10,000 bulb stage when its growth characteristics under certain conditions resulted in the decision to destroy the whole stock. Greenhouse culture in the breeding of freesia varieties was essential because their final use would be under greenhouse conditions. Another factor was that field grown blossoms were seldom of the same quality and color as the same variety grown under glass. All of the actual crosses, seed gathering, record keeping and selection was my own assignment while other items were handled by the close supervision of reliable

employees. The digging, handling and replanting of the bulbs in the greenhouses was all done in the summer, during the college vacation. Little attention was given to the production of plants suitable for the back yard garden. Two or three departures into this field revealed the fact that the correspondence resulting was too time consuming to be continued. Since the florists using freesia bulbs also used other forms requiring similar growing conditions, attention was attracted to the possibilities of additional South African genera, including Gladiolus, Lachenalia, Lapeyrousia, etc., etc.

As previously shown, ample facilities were provided without restrictions. This is most unusual in a program that had to be self supporting. As a consequence many items were undertaken that offered little, if any, hope of financial return. Much data was accumulated and some of the results have been published, such as: Flower Forms in Hybrid Freesias, Growth Irregularities in Hybrid Freesias Induced by X-ray, Color Inheritance in Hybrid Freesia, etc. The use of the x-ray, special chemicals, high and low temperature treatment was made at various times with results that were seldom more than interesting.

Two "breaks" in the freesias gave valuable working material. One was a triploid with 33 instead of the usual 22 chromosomes. Although it was almost sterile, it was used in producing several giant-flowered seedlings which have become commercial varieties. This was possible due to the fact that "varieties" are in reality clones and each clone results from asexually reproduced bulbs (6 to 30 or more per year) from a single seedling.

The second "break" was a small, double-flowered white with modified spike that, except when carefully grown, gave it a grotesque, stunted appearance which caused certain florists to advise that it be destroyed since it obviously was a case of disease. Its genetic possibilities were recognized and immediately tested. The utilization of this form resulted in many interesting, although not always commercially valuable, large double-flowered hybrids. The first double-flowered freesia to be introduced was the yellow variety, named sentimentally for my youngest daughter, Judy, (Fig. 2). This was exhibited for the first time by G. C. Van Meeuwen, of Heemstede, Holland and pictured in their catalogues with the caption: *"Judy, de errste dubbelbloemige Freesia"*. This variety and Elders Double White (Fig. 3) were the only two double flowered varieties considered worthy of commercial introduction and both are still being produced for florists by the California bulb growers.

One of the most intriguing phases of this work was that dealing with the original freesia species which had been used by the first breeders that produced the hybrid forms. Some of these were collected for me from the same area in South Africa that supplied the botanists of the late 18th century with their taxonomic specimens. In the case of the "pink" species *Armstrongi*, the specimens were dug from the original clump of bulbs growing near Humansdorp. These species were valuable both in the analysis of hybrid forms and in the introduction of

entirely new characters. Two examples were in fragrance, one similar to gardenia, the other to rose-geranium, both entirely different from that found in the common hybrids. Some of the species had only recently been described and some were received and grown before botanical descriptions had been published. The principal localities supplying freesia species were Southern Ethiopia, Assegai Bosch, Hanover, Bonnie Vale, Stellenbosch, and Humansdorp. With the exception of the first, all are within Cape Province. The original intent involving the acquiring of the species was to unravel the history of the commercial hybrids. In this work several helpers made very useful contributions. Dr. Ragionieri of Florence, Italy was one of the first to use the "pink" *F. Armstrongi* after it became available in 1904. He supplied, via amiable correspondence, detailed data concerning his own results which included one of the first freesia hybrids. It was described and illustrated in a color print in an Italian publication dated 1884. Dr. David Griffiths of the Dept. of Agriculture sent me the complete file of early articles and related materials on freesia compiled by that remarkable plant breeder of the past generation who worked with many kinds of plants, Dr. Walter Van Fleet. Help in acquiring photo copies from rare volumes in Dr. Green's library of Notre Dame was provided by Father Nieuwland. G. H. Dalrymple of Southampton, England supplied data concerning his work with freesia, also unpublished details of hybridizing by that notable plant breeder of an earlier period, Rev. Joseph Jacob. He also arranged our exhibits at the Royal Horticulture Society's shows in London, England. Much of this material was used in my exhibit in the Floriculture Division at the 6th International Congress of Genetics.

Although my main interest has been with freesias, the gladioli were especially attractive. Due to the extensive planting of the garden type hybrids in the northern part of Indiana and Michigan, I felt the breeding of this plant was already in a highly competitive state. However, one phase of their breeding efforts seemed to have been neglected: the production of varieties that blossom in the greenhouses during the winter. At that time the cost of fuel and labor had not reached the war-time and post-war levels and florists could profitable compete with the gladiolus blossoms shipped from the Florida fields. The hybrid gladiolus varieties so extensively grown during our summers are very diffcult to force into winter blooming without artificial lighting. Early blooming strains of gladioli had been produced some years earlier, mainly in Haarlem, Holland by the the firm of E. H. Krelage and Son and later by C. G. Van Tubergen. These were the so-called "baby glads" which never made any head-way in America because they were not impressive enough to be commercially profitable as a greenhouse crop. Here seemed to be another opportunity for plant breeding to offer a profitable solution.

Another item that had been neglected was the production of varieties with desirable fragrance. Since my collectors in South Africa were more familiar with the gladiolus species than the freesia species, it was relatively easy to acquire several with which to work. Preparatory for this, a survey of the historical items concerning the gladi-

olus species and work of English breeders, revealed several suggestions as to procedure. As might be expected, I made the usual start in this direction by attempting the cross between the night fragrant species *tristis* and the day fragrant *recurvus* which producted the variety Fragrans for Dean Herbert of Manchester, England many years ago. The species *tristis* and *recurvus* were the first obtained and used. The following species with some collected types of questionable classification were added for use in breeding: *alatus, brevifolius, formosus, viperatus, hirsutus, pulchellus, namaquensis, grandis, gracilis, orchidiflorus, communis, watermeyeri, psittacinus,* and *odoratus.* With the exception of *psittacinus* none are to be classed among the tall broad leaved types that may have entered into the making of our common garden hybrids. Most of these are classed as either narrow-leaved or rush-leaved and had not been particularly attractive to plant breeders.

My work with the fragrant gladiolus hybrids began at about the same time as that of Dr. Forman McClean, then at the New York Botanical Garden. From his published statements and by way of our conversations it was learned that our findings in the use of the *recurvus-tristis* hybrid had much in common, however my work included several more species and obviously gave different results. Due to the fact that my hybrids were both winter flowering and fragrant, they were described with very favorable editorials in American and Dutch Florists magazines just prior to the onset of the war. An example is the following quotation taken from an editorial written by T. A. Weston[2] of New York City about blossoms sent to him in February: "Dr. W. P. Morgan . . . has favored us with seven spikes of these gladiolus and the perfume is so strong that hours after unpacking, the delicious odor reaches us as we write, though the flowers are several feet distant. The individual flowers range to 3¾ in. with 10 or more on a stem. To us the odor savors of Freesias and Wallflowers".

Another item that must be taken into consideration in the production of flower fragrance was covered by Dr. Albert F. Blakeslee some years ago in his published studies on scent perception. As an example, I have found many people entirely "blind" to the odor of violets, hence they thought the gladiolus species *recurvus* was scentless. Another example was the variety named "Spicy", the only fragrant variety which we introduced. This had fragrance quite unlike any species being used which, to me, was similar to the heavy, sickening odor of nicotiana or flowering tobacco, however both my colleagues in this project considered it entirely odorless. In keeping with the professional tendency, to date, none of my gladiolus breeding records have been published. My experience has been that such published records usually tell the truth but not the whole truth, hence the breeding can be repeated only with great difficulty, if at all.

Most retail florists show little concern about the fragrance of their flowers. This is largely due to the fact that the flowers they handle are continuously kept chilled by refrigeration and the fragrance

[2] Editor, Florists' Exchange and Horticultural Trade World.

does not become apparent until the flowers reach the warm homes of their customers. The one item that both florist and customer usually agree on is this: are the flowers large and showy?; are they of pleasing color and form? In respect to these items it can be definitely stated that practically all colors, flower forms, blossom size and spike length of the garden gladiolus hybrids have been duplicated. In addition to these, many new flower types were produced in the multi-species hybrids. Each seedling selected to be saved for further observation and bulb increase was given a number and a file card record as to parentage, blooming date, size and number of flowers, length of stem, color and fragrance. Then a "close-up" kodachrome photograph was made of either a single flower or the whole spike. The slides shown are from these routine records. (Figures 5, 5A, 6, 7 and 8 were made from these slides.)

Fig. 5. The dwarf (six to eight inches) Gladiolus species *alatus*.

The many breeders of the gladiolus hybrids produced millions of seedlings, many with gloriously colored blossoms of great size, but none really fragrant and few, if any, responding to greenhouse forcing. This is easily explained since the species that went into the making of our garden forms lacked the genes essential to the production of these characteristics. Efforts to determine the definite species that were used by the originators in England, Holland, France, and America have been rather confusing. Most agree that only a few of the more than 150 known species including *psittacinus*, *cardinalis*, and *oppositiflorus* were used by the hybridizers. These are all robust growers and, without the background of modern genetics, few breeders would risk using

Fig. 5A. Gladiolus *viperatus*. The easily grown fragrant green Kalkoenje of South Africa.

Fig. 6. The fragrant Gladiolus species *odorata* which was the seed parent of the hybrid shown in Fig. 8. Corms of this species are tall and pointed instead of the usual broad, flat form.

frail, inconspicuous species that possessed a single desirable characteristic.

Since our post-war conditions are even worse than those of wartime in the production of bulbs that require a lot of costly hand labor, it is doubtful that my findings will be needed by us in any future commercial bulb production; therefore any information I have is passed on in the hope it may be of some value to those interested in gladiolus breeding. The seed of gladiolus species can readily be obtained from the Cape due to the fact that several companies and individuals specialize in these items. The importation of bulbs is restricted. I would definitely recommend the purchase of collected seeds from South Africa rather than that which might be supplied by American seed or bulb specialists. This is due to the fact that many species are quite variable. For example *recurvus* may vary from lemon-yellow through various shades of light blue to deep reddish-purple. Furthermore, there is great variability in fertility. This was true in one lot of bulbs of *tristis* purchased in California. They were almost sterile while *tristis* obtained from Africa produced full pods of seed when the same crosses were repeated. Seedlings of the species may be grown in the open ground in our locality and they flourish under the climatic conditions of southern California. I have found that the cross between the species *recurvus*

and *tristis* produced hybrids having several types of day fragrance differing from the violet-like odor of *recurvus*. Although I have back-crossed and inbred several of these hybrids with interesting results, the quickest method of getting large flowered types would be crossing this hybrid using a garden gladiolus as a pollen parent. Many of the resulting seedlings will be mildly fragrant and nearly as large and robust as the garden types. Garden type varieties were grown for me in Florida and the flowering spikes shipped to Indianapolis where the pollen was used in hybridizing. More than fifty named varieties were used. In general, the older namer varieties and *primulinus* hybrids were the most viable. Some species failed to make seeds with either *tristis* or *recurvus* or the other species crosses attempted, however they crossed with the *recurvus-tristis* hybrid which served as a convenient medium to combine one or more forms with it into a multi-species hybrid. The resulting plant could then be used as a seed parent and crossed finally with the garden hybrids to produce a plant with the large, showy flowers that we have come to expect when the gladioli are used in decoration.

The species *tristis* was used by some of the first hybridizers of gladioli. An English form produced by Colville in 1823 and known as Colvillei and later the "baby-glads" from Holland's C. G. Van Tubergen, all had *tristis* as one parent. These and most of the hybrids between the garden gladioli and *tristis* are practically scentless. Contrary to the published work of McClean, by own results have been much better by using *recurvus* as the seed parent. Most of the resulting plants are sturdy with broad leaves and large, showy flowers on tall stems. They are winter blooming and most of them are mildly fragrant similar to *recurvus*.

One question that has often been asked is, why do the species that you use, cross so freely? The suggested answer may be had by reviewing the cytological studies on the gladiolus species and garden varieties by Bamford. As indicated in these publications most of my species had a 2N chromosome number of 30. The exceptions were: *formosus* and *orchidiflorus* with 45, *psittacinus* with 90 and *cummunis*, a European species with 180. Hybrids among most of the South African species possess a diploid number of 30. The garden hybrids that have been studied are tetraploid with the 2N number of 60. The resulting plants produced by crossing a garden gladiolus with a species hybrid normally would be a triploid with 45 chromosomes and usually would be sterile. Sterility and fertility are not to be explained entirely by chromosome number but expected results in breeding largely support this interpretation.

One series of crosses has been especially interesting with further possibilities suggested. This utilizes the species *odorata* that blooms in the greenhouse from late November through January. This species has small, dull colored flowers with the clove-like fragrance of carnations, a type of fragrance that most people seem to like. This species was used in many crosses with little success but the following gave excellent results. The 30 chromosome species hybrid of *recurvus-tristis*

was crossed with the old variety Los Angeles having 60 chromosomes. Some of the flowers of the resulting hybrids resembled Los Angeles but blossomed at about the same dates as the *recurvus-tristis* hybrid and had faint tea-rose fragrance. Their chromosome number was never determined. These hybrids were then used as the pollen parents on the 30 chromosome species *odorata*. The resulting seedlings all had the intense carnation fragrance. The medium size flowers were much larger than *odorata* but varied in color from the clear, even, deep pink of Los Angeles to bright crimson. Some of these seedlings have produced seeds. Here seemed to be some interesting possibilities that should be pursued.

For anyone interested in the shorter stemmed gladiolus forms suitable for table decorations, the hybrids with the brick-red species *alatus* are truly beautiful. Using *alatus* as either pollen or seed parent with the *recurvus-tristis* hybrids give excellent results although they are not noticeably fragrant.

The foregoing description of methods and results have been illustrative of some of the plant breeder's "stock in trade" that at times have been acquired by devious and tedious trials over a period of years.

Fig. 7. Pink hybrid #95. Pollen parent garden variety "Los Angeles" and seed parent the hybrid *recurvus* x *tristis*.

Fig. 8. Crimson seedling #738 (Three species and a garden variety.) Pollen of seedling #95 on the species *odorata*. Has carnation fragrance.

Each project capitivates his interest and the future continuously reveals the success or failure of his planned combinations in a procession of living things. To see the results of several generations of genetic reassembling culminate in a flower of great beauty, in wanted color, size and form, brings an unforgetable thrill. All of this is quite fascinating and nice to reflect upon, however any comprehensive breeding program is usually dependent on commercial outlets for its existence. This has been the situation with our program which I have just described. Although it flourished and expanded during the years of depression, it could not withstand the war-time restrictions and rise in labor cost. The enterprise was devoted exclusively to the production of bulbs of freesia and related types. This required a large supply of hand labor at planting and harvest, and, to avoid diseased bulbs, the frequent shifting to suitable land with available irrigation. The strict restriction in the extension of irrigation, except for food production, and the shortage and cost of labor, forced the decision to abandon field production. This was done very near the end of the war in spite of a demand for our bulbs that was greater than the available supply. The growers that obtained the stock of our varieties, many of which were patented, were permanent residents of the area and bulb production was mainly a sideline to vegetable growing. The stock of several varieties of gladioli about ready for introduction were destroyed early in the war period and the stock of all other varieties reduced to the barest minimum to be increased for introduction after the war. This idea was quite a delusion because conditions favorable to our program have become worse during this so-called post war period. The present influx of Florida grown gladiolus blossoms for use by northern florists are now listed, not in dozens or hundreds, but by tons, therefore that potential market has changed. The continued rise in cost of fuel and labor has now dampened any idea of reentering commercial bulb production.

Each fall for the past five years it has been the decision to totally abandon the remaining aspects of the enterprise and to turn the space involved over to more profitable use. In spite of all those decisions, you will find that small house in a range of greenhouses otherwise entirely devoted to growing roses, planted with unnamed freesia varieties, freesia species, gladiolus species, and gladiolus hybrids to blossom again in an array of color and fragrance. With the memories of their past contributions and the thoughts of their war thwarted possibilities, *those captivating irids* "just naturally get under your skin and it is hard to let them go".

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ANTHROPOLOGY

Chairman: G. A. Black, Indiana University

Mrs. G. F. Martin, Evansville, was elected chairman for 1952.

ABSTRACTS

Archaeological field methods and C^{14} dating. Glenn A. Black, Indiana Historical Society.—The new method of determining dates of archaeological complexes which has been presented to us by the physicist has been accepted without reservation or disclaimed without qualm depending upon whether the date derived did or did not "fit" individual dogma and preconceptions. The physicist is a disinterested party interested in the technique and in the reliability of the mechanics and methods involved. He is, however, at the mercy of the archaeologist and the reliability of the carbon sample with which he works is no greater than the methods by which it was removed from its original context. It, therefore, behooves the field archaeologist to review his methods and to refine them to the extent that with each carbon sample a complete and entirely reliable series of data shall accompany it.

A description and distribution of Yankeetown pottery. Emily J. Blasingham, Indiana University.—There has been no previous description of Yankeetown Pottery. The type site is located in Warrick County, near the village of Yankeetown, thus the name for the type.

Other sites producing the ware are located in Warrick, Vanderburgh, Posey and Gibson Counties in Indiana, Henderson County, Kentucky and several locales in Southern Illinois. The Henderson County site is the only known Kentucky site and it is on the north side of the Ohio River.

Surface types are varied and indicate a high degree of development of the ceramic tradition. Incising, applied fillets, notching are involved in decorative treatment while the overall vessel surfaces may be plain or cord marked, with an emphasis upon the former.

Chronologically Yankeetown appears to be later than Baumer-Early Woodland in the same area and earlier than fully developed Middle Mississippi as exemplified at Angel Mounds Site. It also appears to belong to the long-lived Baytown Series of ceramic types found over a large area of the central Mississippi River Valley.

Economy, residence and descent among non-literate peoples. Harold E. Driver, Indiana University.—Matrilineal descent prior to 1492 occurred principally in tropical latitudes where subsistence was mainly on plant foods. The obtaining of wild foods plants was everywhere

chiefly a woman's task. Where domesticated plants were cultivated by hand methods, women in many localities did all or most of the farming. Thus there was a positive correlation between matrilineal descent and the dominant role of women in the subsistence pattern.

Patrilineal descent, on the other hand tends to be correlated with pastoralism, and with the use of draft animals and the plow for agriculture. In both these types of economy men play the dominant role. Patrilineal descent also prevailed in areas of intensive hand cultivation, such as the Far East and Mexico to Peru, where men did most of the farming.

Where strict rules of descent have not crystalized, residence rules sometimes reflect the same tendencies. For example, the sub-arctic and most of the Pacific coast of North America are uniformly bilateral in descent but patrilocal in residence. The hunting and fishing economies of these areas give men the dominant position as provider of food.

The use of photography in ethnological field work. ROBERT F. FORTH, Indiana University.—Instead of making a straight documentary record of ethnological field materials, the documenting should be planned as a whole and edited for purposes of emphasizing certain limited themes. In order to accomplish this it is necessary to place two elements in juxtaposition to imply a third one. For example, it would not be enough to film a sequence showing the breaking of a law and punishment, but there should be a third sequence showing the effect of the latter on the community.

The sunflowers from Tularosa Cave, New Mexico. CHARLES B. HEISER, JR., Indiana University.—Among the prehistoric materials recovered by the Chicago Museum of Natural History at Tularosa Cave, New Mexico, are the heads of several sunflowers. One species has been identified as *Helianthus annuus* var. *lenticularis*, the common wild sunflower. Two other species are also represented but their identity is more doubtful—one is probably *H. praetermissus* and the other is apparently from one of the perennial sunflowers. These specimens are of particular interest in that they represent the first definite plant remains of the sunflower from the Southwest.

A cache of baked clay artifacts found in Indiana. FRANCES PATTON MARTIN, Evansville.—A cache of about 200 baked clay artifacts was found during the winter of 1949-1950 on a Late Archaic Shell Mound Indian site at Clarksville, Indiana. Each of these ceramics was made from a handful of clay compacted with secondary manipulation of pinching and impressing to form rounded knobs and depressions plus punctateing on a few pieces.

Many artifacts similar to these have been found in the Mississippi Valley and the Lower Sacramento valley but this discovery is the first reported in the present Ohio valley and the first mass deposit reported from any site where stones are plentiful. Although the use of these objects is unknown, they always have been regarded as stone-substitutes.

They were made without tempering material of any kind and were used primarily by Indians who did not make or use fired clay vessels.

An application of distributional dating to an anthropological problem. GEORG K. NEUMANN, Indiana University.—When a comparative study is made that involves the distribution of the varieties (physical types) of Indians within a certain time horizon, historic linguistic distributions, and historical data dealing with migrations, the distribution of a set of ethnological traits whose antiquity are unknown can often be placed chronologically. The Star Husband tale of the Plains area can be cited as an example. The distribution of the tale can be explained by the late prehistoric movements of three varieties of Indians who can in turn be linked with tribal and linguistic groups.

The use of tape recording in anthropology. THOMAS B. NOBLE, Indianapolis.—The quality of sound reproduction by magnetic tape is equal to the ability of the human ear to hear.

Compared with other and previous devices, tape has been brought to a practical portability that enables all sound to be caught and preserved, anywhere.

There is a peculiar value to the spoken word over the written, in that it is less inhibited and more truthful. Particularly with Indians, the conversation has little of propaganda and understanding has a more solid foundation when based on it. Translations by natives into English gives even better Indian color.

The author has begun a sound library for the capture of the living voice and spirit of the men in the anthropologic sciences in the southwestern National Park Service. This promises to be a growing and live project that can lift their work from the dusty mimeographs of museum basements.

In collecting Navaho chants, songs, and legends the author has been preserving that branch of Americana that has a chance of being lost as the years pass and changes occur on the reservation.

The Shawnee in relation to Tecumseh's proposed uprising. ERMINIE W. VOEGELIN, Indiana University.—Despite the fact that Tecumseh and his brother The Prophet were Shawnee, neither of these two leaders succeeded in enlisting more than a handful of Shawnee in their proposed general Indian uprising. The non-participation of the Missouri Shawnee seemingly is explainable on the basis of a decision reached by this group sometime after the battle of Point Pleasant in 1774, but the background for the decision of the other large Shawnee group, the Ohio Shawnee, not to participate, was apparently more complicated and the subject of a good deal of councilling on the part of the Ohio Shawnee leaders. Material in the Draper Mss. indicates the important roles that John Coldwater, a relatively unmentioned Shawnee chief, and Blackfoot, a well known Shawnee chief, played in keeping the Ohio Shawnee out of Tecumseh's and The Prophet's conspiracy.

Aboriginal American Medicine and Surgery

William R. Adams, Indiana University

The practices of curing and healing among the American Indians were so tightly bound with the mysticism of a shaman's chant that it sometimes comes as a surprise to find some of these aboriginal techniques were fore-runners of present-day medical methods. For our knowledge of aboriginal diseases and their treatment we are largely dependent on inadequate early historical accounts. While many of these diseases and surgical procedures are reflected by study of skeletal material, others leave no bony markings.

In the following remarks I have tried to gather available data and at the same time omit obviously magical methods of curing, although not with the intention of belittling the importance of their role. Indeed, psychosomatic medicine is of significance in any culture, and particularly in one where the supernatural causation of sickness is stressed.

Of all diseases known among the American Indians, probably the greatest bone of contention has been the origin of syphilis. Although entire books have been written on the subject, there is still much disagreement on the pre-Columbian history of the disease, some authors claiming to have demonstrated it among prehistoric skeletons, and other workers denying it. It seems certain that the disease was previously unknown in Europe or the Americas in the virulent form first reported a few years after the discovery of the New World. Possibly the Old and New Worlds each had a milder form of syphilis, that upon contact resulted in a more violent strain affecting European and Indian alike.

Prehistoric skeletal remains give silent proof of the relative commonness of various forms of arthritis. Hooton (8) has reported it in 13.12% of Pecos Indians, and according to Ashburn (2) chronic arthritis was present in about the same proportions before and after European contact.

Mastoid infections were fairly frequent among the prehistoric Americans, although mastoid abcess was rare.

McCurdy (10) has reported one cranial osteosarcoma from Peru and Ritchie and Warren (11) have described a case of multiple myeloma (a primary malignancy of the bone marrow), but demonstrable cancer seems to have been extremely rare among both the prehistoric and historic Indians. Cases of osteomyelitis and periostitis from the Maya area have been recorded by Corlett (3). Denninger (4) has described an osteitis fibrosa from an Illinois mound. This crippling degenerative disease, in which the bone is replaced by fibrous tissue, is due to parathyroid tumor. Osteomata (hard bone tumors) of the walls of the inner ear seem to have been fairly common among some Indian groups. These exostoses are thought by Adis-Castro and Neumann (1) to have

a hereditary basis and that the high incidence found in some cultures is a product of inbreeding in higher social strata.

The presence of deficiency disease among American Indians is recognized mainly through an abnormal porosity of the cranium known as symmetrical osteoporosis. This condition, due to loss of calcium, phosphorus, and vitamins C and D from the diet, is believed to be caused by extensive agriculture.

Heart disease has been considered by Gordon (6) as rare among American natives. While an apparently low incidence of heart disease may have been due to the aboriginal way of life, it may be because it was usually confused with other chest complaints and treated accordingly.

Ritchie (12) has recovered arteriosclerotic plaques from a prehistoric New York site, and Wakefield and Dellinger (13) have demonstrated them from Ozark Bluff Dwellers.

Minor gastro-intestinal disorders were very common among the aborigines, most often due to alternate fasting and glutting. Natural remedies: emetics, carminatives, counter-irritants, purgatives, etc., were widely used. Ashburn (2) describes dysentery among the North American Indians and suggests that the bacillary type was indigenous and the amoebic form introduced to America from the Old World.

Respiratory infections were common among northern tribes, particularly those in the Great Lakes Area. Bronchitis, pleurisy, pneumonia, and tuberculosis were usually grouped together as a pain in the chest and treated accordingly. Although some authors question the pre-contact existence of tuberculosis, Ashburn (2) mentions Peruvian art showing spinal deformation and facial expression characteristic of tuberculosis of the bone, and Hooton (8) has recorded one Pecos skeleton he believed to represent Pott's disease. In the post-contact period pulmonary tuberculosis was one of the greatest scourges of the American Indian.

Diseases of the eyes and conjunctiva were relatively common, and many authors blame them on irritation by the dense smoke-filled atmosphere of aboriginal habitations.

Serious neurological disorders were comparatively rare, the mild forms of depression and hysteria being satisfactorily treated by the medicine man's performances.

On the basis of available descriptions, malaria was present in North, Central, and South America, although some authors have argued for the post-Columbian introduction of the disease from Africa.

The occurrence of yellow fever, typhoid fever, scarletina, and diphtheria before European contact is doubtful.

A number of parasitic skin diseases have been described from the tropical and semi-tropical areas of the western hemisphere.

Dental disease was almost universal among the American Indians in contradiction to the frequent references to perfect sets of teeth. 12-90% of prehistoric North Americans possessed one or more carious teeth according to Krogman (9). Among the Peruvian remains, however, there is a low incidence of caries, but a very high one of

pyorrhea. In addition to these ailments we find evidence of abnormal retention of deciduous milk teeth, supernumerary teeth, impactions, etc.

Perhaps the most sensational among primitive treatment methods is that of trephining or cutting into the skull and removing a piece. This operation was most frequently performed in accordance to the sound surgical principle of fracture decompression, although at times perhaps with a view to releasing evil spirits.

The practice of trephination centers in Bolivia and Peru where 5-6% of skulls show one to five openings. Freeman (5) has correlated this high incidence with the prevalence of slings and spiked clubs among the Peruvians.

The openings were made by sawing, cutting, scraping, drilling, and by combinations of these. In large openings plates of skell, gourd, or beaten silver were inserted to prevent herniation of the brain tissue. Most trephining was performed at the seat of the fracture, although some are at a distance and appear to be deliberate attempts at symptomatic relief.

The operation was apparently rarely fatal, many individuals survived for many years as evidenced by the amount of healed bone. Some of those showing no cause and no healing may actually represent a post-mortem practice session.

The setting of fractures was normally aided by splints of wood or bark, sometimes padded with wet clay or wrappings of rawhide. Through lack of, or faulty, manipulation, malpositioned repairs with extensive callus formation are common.

Amputations were occasionally performed and Peruvian pottery depicts employment of the skin-flap technique and subsequent use of artificial limbs. Removal of fingers was fairly common as a religious rite or tribal punishment, but therapeutic amputation seems to have been very rare.

In cases of foetal malposition midwives frequently attempted manual reversal, either internally or externally. Cortlett (3) cites an alleged custom among West Indies women, wherein they perform Caesarian sections on themselves in cases of difficult birth. These are supposed to be generally successful and may be repeated in successive pregnancies.

Bleeding or venesection was a widespread remedy for headache and fevers, aches and swellings. Although not without some merit this treatment was of largely magical basis.

Cupping and sucking in addition to its shamanistic applications in the case of "foreign bodies" was logically used for snakebite, and removal of pus from wounds and ulcers. Cupping with a buffalo horn followed by a counterirritant was employed for chest pain.

Sweat baths were utilized for the relief of arthritis, fatigue, and constipation in addition to their ritualistic and social usage.

Bandaging and strapping were employed in chest inflammations and to control hemorhage. Laced corsets of bark were occasionally applied for spinal or abdominal ailments. Freeman (5) illustrates an

Inca bandage over an unsuccessful trephination, consisting of cotton covered with gauze and held in place by lashings of fine woven cord.

Heizer (7) shows the use of enemas to have been very widespread with applications varying from treatment for constipation, diarrhea and hemorrhoids, to the administration of wine by the Aztecs and of the narcotic "parica" by South American tribes.

Coca leaves were used by the Inca for anaesthetic purposes, although many tribes had to rely on tobacco and alcohol. Freeman (5) reports that hypnotism has been used for primitive surgers.

Suturing was employed for wounds by many tribes. Sutures of human hair, vegetable fibers, and sinew were used. South American tribes employed a forerunner of the modern skin clips by allowing leaf-cutting ants to pinch the edges of a wound together, then twisting off their heads.

Some tribes irrigated puncture or complicated wounds, and others cauterized by means of fire coals, heated stones, or burning cotton. Among some groups wicks of twisted cloth or bark fibers were used as drains. Gum abcesses were treated by lancing and cauterization, while aching teeth were frequently removed by means of a bone punch.

The materia medica of the prehistoric Americans was an extensive and often revolting list, including emetics, laxatives, purges, febrifuges, intestinal antispasmodics, diuretics, antidysenterics, antirheumatics, antihemorrhagics and many others. A substantial number out of that list have been incorporated into modern medical practice. Many others, it is true, were of purely imaginary and psychic action. A large number of these indigenous cures have not yet been satisfactorily identified and analyzed due to ambiguous descriptions given by early sources.

Thus as a general rule we find that wounds and illnesses for which the cause was obvious were treated in a logical manner. However, when the cause was obscure or when their rational treatments failed, these aborigines like all God-fearing men invariably appealed to the higher power of the supernatural.

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Potentialities of Somatotyping for Secondary Schools

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The science of physical anthropology has become in the last two decades a busy field of research insofar as it concerns living subjects and the potential correlations with other fields of human biology. Possibilities have been indicated by Williams (12), Montagu (7), Hooton (6), and Boyd (1). The scheme of Sheldon for physique classification called "somatotyping" (9), and his temperament classification (10), offers a handy tool for such quantitative determination of individual differences. It has been widely used with good results reported, such as Draper (3) with medical correlations, and Heath (5), Glueck (4), and Cureton (2).

There are, of course, limitations and questions concerning the effectiveness of the Sheldon technique. The permanence of the somatotype is in question. What, for instance, are the effects of nutrition on it? What is the permanence of the somatotype given good health over a period of years? Have the high correlations been subjected to rigorous enough controls?

One of the prime difficulties of the Sheldon method, however, is one which is common to many achievements in science. The equipment necessary to take photographs in a standardized fashion, while not extraordinarily expensive, precludes its use under many conditions. The analysis of the anthropological data obtained to produce the somatotype is burdensome. In the field of secondary education all of this is not impossible to obtain. But the question is, is it so elaborate that the probability of its use is remote in secondary schools? This would probably have to be answered in the affirmative. Is the Sheldon method an illustration of sending a man to do a child's work? Can the Sheldon system be made simpler and still retain its accuracy? To broaden the research base in physical anthropology some effort must be made to simplify the anthropological analysis of an individual. Anthropologically unskilled persons should be able to use this data obtained by relatively unskilled but trained individuals, and use it in some field for which they have training and skill, to discover correlates, if any, with this data. Can a high school teacher somatotype with some accuracy without elaborate equipment?

To answer the query as to the possibility of the untrained somatotyping with some degree of accuracy, it must be assumed that this is possible without the use of the photograph technique. Sheldon seems to have confidence that this can be done with a high degree of accuracy by someone well acquainted with the theory and technique as he mentions frequently in his books the somatotyping he and his colleagues have done on the beaches and on the streets, and we assume that this was done with a feeling that some accuracy was obtained. Cureton (2) discovered that with his staff having received only a brief explanation of the components, it was possible to obtain such a high

correlation with the photographic analysis that the standard deviation was only one-half of a point on the Sheldon scale. It seems safe to assume, therefore, that the subjective judgment of a trained person may very well be highly accurate in somatotyping.

The discovery of any correlates with the somatotyping process in the personality range of the individual requires a huge outlay of time, money, and effort. The Heath study (5) attempted this. Sheldon's survey of delinquents (8) uses psychiatric data in an attempt to obtain some comparison with their physiques. Glueck (4) concludes that the delinquent has a high degree of mesomorphy in comparison to the average non-delinquent. The Stolz's (11) used the Sheldon technique in their survey of adolescent development. The role which could be played in education, guidance, and athletics, by somatotyping affords too bright a prospect to disregard.

The purposes of the investigation outlined here are to answer the following four questions:

1. Can somatotyping be done with some accuracy by a trained person without photographic equipment?
2. Can somatotyping be done by subjective judgment with a fair degree of accuracy?
3. What is the stability of the somatotype between the ages of fourteen to eighteen?
4. What correlates seem to be present, and are suggested, with the somatotype and other features of the individual?

The methods by which this was carried on were admittedly sketchy and rough. There had to be a rapport between examiner and the boys which was not always possible to obtain, or keep, over a four-year period. Therefore, the following results are not offered as the last word, nor a doctoral dissertation on the subject. They are offered with no pretense that the results are any more than they are or seem to be. They are offered in the hope that the members of the Academy in the psychology and anthropology sections will be enlivened to pursue one of the paths suggested with more precision than this author could accomplish.

Boys were selected at Thomas Carr Howe High School in Indianapolis to cooperate in this project beginning in 1948, by a personal interview with the examiner. Some effort was made in this selection to find what seemed to be as many possible somatotypes and types of personalities. Twenty-one boys have cooperated in this period of time with this project.

Each boy was given a somatotype examination, which consisted in the examiner finding the data outlined on a "Somatotype Data Sheet." A standard anthropometer (Cenco, Cat. No. 73115) was used. (Fig. 1). Then a subjective judgment was made by the examiner of the boy's somatotype.

The next step was to work out the somatotype by regions, with the general somatotype as a summary, as indicated by Sheldon. A

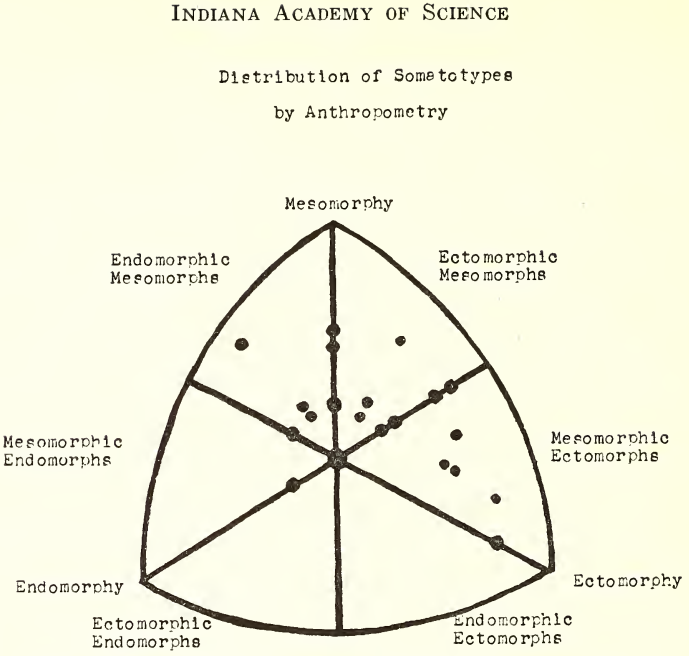

Fig. 1. Distribution of somatotypes by anthropometry.

temperament classification was also worked out in accordance with the suggestions of Sheldon. This was done on each boy by the examiner and also by another person. Other data was recorded by the examiner. The twenty-one boys were examined at least once on all scores.

The results obtained can be seen in the attached tables. (Table I). Although the survey was limited by many factors, chief among them being the small sample, the inadequate control factors, and the short period of time in which the project was carried on, several probabilities emerge. They should serve to forecast the probable results that might result from a more adequate study. This is, in fact, an exploratory venture in an effort to produce some more satisfactory research on the part of some group in the Indiana Academy of Science.

Whether or not somatotyping can be done with some accuracy by a trained person without photographic technique is shown by the correlation of .71 for endomorphy, .81 for mesomorphy, and .74 for ectomorphy between the subjective inspectional judgment and the somatotypes determined by the height and weight ratio. There is also a correlation of .65 for endomorphy, .80 for mesomorphy, and .81 for ectomorphy with the subjective judgment and the actual anthropometric data.

It is to be noted that although some somatotypes did change, the predominant component did not in any case. Correlations between the original measurements and the latest measurement show .81, .66, and .50 for the three components.

The correlation between somatotype judgment and the temperament classification (Table II) shows .74, .53 and .83, and .65, .69, and .77 between measurements and temperament classification. Indicated also is the comparison of temperament classification by two observers on the same boy with correlations of .79, .79, and .56.

Although the following results should best be subjected to statistical analysis if the sample were larger, several interesting observations can be noted. It must be emphasized, however, that they remain as observations and not conclusions. General athletic ability seemed to be correlated most highly with the predominant mesomorphs. Two exceptions among the twenty-one were noted, but in each of these cases the athletic record was mediocre and they were rapidly being supplanted by younger and better fitted individuals. It seemed, in other words, that their participation in athletics was initiated by their evident more mature development for their chronological or school age. Difficulties which necessitated action by the Dean's office were confined wholly to the mesomorphs, but by no means were all the mesomorphs in this classification. Ratings by each class teacher as to the personality traits designated on school records for each of the subjects showed no adequate correlation with any of the observable traits. This was also true of academic grades. Data on vocational disposition, majors and minors, favorite subjects, and favorite teachers were inadequate to make any justifiable observation. It seemed to be true, however, that the predominantly mesomorphic individuals were quite impressed with any teacher who dealt with his class in a firm manner, while the ectomorphic, and the two endomorphic boys had many personal prejudices and dislikes in this group of teachers. Intelligence quotients and other standardized test data yielded no observable correlation. In conclusion, general attitudes observed showed that the mesomophs had great respect for formal and strict discipline, although they were the only ones in trouble with the authorities. The two with a high endomorphic component showed an easy-going nature which was quite evident in all their relationships. Mesomorphic individuals as a group had an objective relationship with the teacher, characterized by an easy friendly manner, with a sincere desire to work hard for only a few teachers, and with a cat and mouse attitude to the others. The two endomorphic boys with their easy-going natures tried to be friendly with everyone, and neither one showed any inclination to work hard. The ectomorphic persons caused no trouble for the teacher in class, but attempted to work hard at all times, applying themselves especially well in those subjects which interested them.

Those disciplines using the Sheldon techniques and those studies just published indicate a strong tendency to regard the somatotyping procedure with a great deal of respect.

How can this be applied on a practicing basis, or as an attitude, by secondary school teachers, or by any individual dealing with growing persons? What are the minimum essentials which such people must know before the technique can have any value? How can this information be used in guidance activities of the modern school in

TABLE I.—Data Summary

Number of Participants	Age	Date	Somatotype by Judgment	Somatotype by Height/Weight Cube Root	Somatotype by Anthropometry	Height	Weight	Age	Date	Somatotype by Judgment	Somatotype by Height/Cube Root of Weight	Somatotype by Anthropometry	Height	Weight	Age	Date	Somatotype by Judgment	Somatotype by Height/Cube Root of Weight	Somatotype by Anthropometry	Height	Weight	Temperament Classification by Examiner	Temperament Classification by Others
1	15	5 1948	354	354	354	72.25	168	16	4 1949	354	353	353	74	184	17	5 1950	354	353	354	74.5	190	353	453
2	16	12 1948	352	352	242	70.5	167	18	5 1950	352	352	343	72	178								453	462
3	15	1 1949	441	443	442	71	161	17	6 1950	451	451	453	73	195								453	562
4	16	1 1949	246	344	256	72.5	160.5															265	354
5	16	3 1949	363	271	353	67.5	168															443	543
6	16	3 1949	344	453	344	73.25	182	17	7 1950	453	453	344	74.25	193	18	4 1951	454	452	453	75	205	453	454
7	16	3 1949	236	235	226	73.5	153															335	343
8	16	3 1949	253	353	243	69	152	17	5 1950	254	362	244	69	166								344	443
9	15	4 1949	225	345	226	68	127.5	16	5 1950	345	344	236	69	138.5								334	345

10	14	4 1949	344	344	344	71.5	154	16	3 1951	354	352	444	73.25	186								454	453
11	16	5 1949	354	354	354	70.5	156.5	17	8 1951	354	354	344	70.75	160								454	454
12	17	4 1949	542	543	433	72	183															543	644
13	15	5 1949	354	353	353	69	150.5	16	6 1950	254	353	254	70	157	17	10 1951	354	254	354	70	158	354	444
14	15	5 1949	354	352	354	67	144	16	5 1950	353	362	353	67.25	153	18	8 1951	353	452	343	68	155	353	363
15	16	12 1949	444	443	443	73	173	16	5 1950	444	443	443	73	173								444	444
16	16	4 1948	354	354	344	73.75	180															354	343
17	17	10 1950	363	452	352	72.5	187	17	1 1951	362	451	452	74	205	18	7 1951	352	352	352	75	200	552	562
18	15	11 1950	345	235	245	70	130	15	1 1951	245	145	235	70	128	16	11 1951	245	345	245	70	139	344	443
19	15	11 1950	245	245	234	70.5	140	15	1 1951	245	245	244	70.5	138								334	444
20	15	11 1950	335	335	345	70.5	137	15	1 1951	335	235	234	70.5	132								435	445
21	17	2 1951	345	244	334	72.25	154	17	6 1951	344	343	344	72.25	167								354	454

TABLE II.—Correlations; Pearson's Coefficient of Correlation

Endo-morphy	Meso-morphy	Ecto-morphy	Somatotypes	
.71			Endomorphy	Subjective Judgment
	.81		Mesomorphy	and
		.74	Ectomorphy	Height-Weight-Cube Root
.65			Endomorphy	Subjective judgment
	.80		Mesomorphy	and
		.81	Ectomorphy	Anthropometry
.81			Endomorphy	Original Measurements
	.66		Mesomorphy	and
		.50	Ectomorphy	Latest Measurements
			Somatotypes and Temperament	
.74			Viscerotonia	Somatotype Judgment
	.53		Somatotonia	and Examiner's Tempera-
		.83	Cerebrotonia	ment Classification
.65			Viscerotonia	Somatotype Measurements
	.69		Somatotonia	and Examiner's Tempera-
		.77	Cerebrotonia	ment Classification
.79			Viscerotonia	Temperament Classifica-
	.79		Somatotonia	tion of Examiner and
		.56	Cerebrotonia	Classification by Someone else
Viscero-tonia	Somato-tonia	Cerebro-tonia		

physical education, health, discipline, interest, social and personality maturation, and methods of teaching? What minimum equipment and tests are necessary to make the individual student analysis adequate to help in this guidance?

This knowledge, leading to an attitude on the part of the teacher, should improve public education in precisely the place where it seems most deficient. First, it should aim the attention of the teacher on the individual as an individual. Second, it would encourage study of the whole child continually, while in school, rather than the present haphazard procedure. Third, it should assist guidance by the individual teacher, which is where most guidance seems to be centered in the public school, rather than in a busy guidance official. Fourth, because of its many and high correlations, somatotyping should make unnecessary the multitude of tests and critical observations which are

now considered necessary for an accurate appraisal of the child. It should shorten the analysis procedure of the school for each child to a more complete picture, yet without elaborate batteries of tests and interviews. Since the public school, especially in its crowded condition, tends to regiment its handling of the individual student because time, money, and staff preclude a complete and thorough examination of each student, a shorter method of perceiving the whole child seems to be in order. This method is similar to the statistical quality control procedures used in large industries, where inspection of each part of each unit is impractical and costly, but testing and examination by regulated probabilities make the inspection system adequate with a very low degree of probable error.

The Sheldon method, streamlined and shortened, simplified and standardized, aimed for the public teacher, may accomplish this end. This study indicates a possible direction that it might take.

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BACTERIOLOGY[1]

Chairman: EDITH HAYNES, Indiana University

R. C. Bard, Indiana University, was elected chairman for 1952

ABSTRACTS

Temperature effect on radiation damage in bacteriophage. C. S. BACHOFER, University of Notre Dame.—In order to establish the effect of temperature on the *direct* action of ionizing radiation in biological systems, bacteriophage T1, specific for *Escherichia coli*, strain B, was irradiated with x-rays at temperatures from 77° K to 310°K. Material was irradiated *in vacuo* in a specially constructed chamber to prevent frosting, liquefaction of air, and interference of oxygen. Three series of experiments utilized 1) phage in broth, lyophilized; 2) phage in broth, vacuum-dried; 3) phage in chemically defined medium, vacuum dried.

No inactivation due to temperature alone was observed at temperatures as low as 77° K or as high as 310° K, for the duration of the experiments.

Experimental results show that survival of bacteriophage after irradiation with a given dose of x-rays is inversely proportional to the temperature at which they are irradiated, that is, there exists an inverse correlation between radiation damage and temperature. The relationship between temperature-of-irradiation and survival varies with the physical state of the irradiated virus. This has been defined mathematically for the three sets of experiments listed above, as follows:

1. Phage in broth, lyophilized.
   The relationship between titer and temperature is
   $$y = a - 1.54x$$
   where y is the titer, expressed in millions of phage particles per ml, at a given temperature-of-irradiation x, when a is the titer at O° K.
2. Phage in broth, vacuum-dried.
   $$y = a - 3.28x$$
3. Phage in chemically defined medium, vacuum-dried.
   $$y = a - 1.65x$$

Respiration of *Clostridium perfringens*. R. C. BARD, Indiana University.—The obligate anaerobe, *Clostridium perfringens*, utilizes oxygen at a rapid rate in the presence of glucose. The respiratory rates are comparable to those of aerobic organisms with $Q_{O_2} = 110—180$, $Q_{CO_2} = 190 — 310$, RQ = 1.6 — 2.0. Respiration is not inhibited by 0.001

[1] Joint session of the Indiana Academy, Bacteriology Division, and the Indiana Branch, Society of American Bacteriologists.

M potassium cyanide suggesting the absence of heme-type respiratory catalysts. A flavoprotein-type respiration may be operative but hydrogen peroxide does not accumulate nor does addition of large amounts of catalase reduce the quantity of oxygen consumed. Inorganic phosphorus stimulates the rate of respiration and is converted to high energy phosphate compound(s) although stable phosphate compound(s) also appear to be formed. Iodoacetate and α, α'-dipyridyl inhibit respiration. The former finding suggests the participation of sulfhydryl enzyme(s) involved in respiration. The latter finding indicates the probable functioning of the metallo-aldolase known to be present in this organism (Bard and Gunsalus, 1950). Iron-deficient cells respire weakly with the accumulation of pyruvate. This finding suggests a role of iron in respiration, probably indirect in the sense that the pyruvate dissimilatory mechanism is iron-dependent, either for its formation during growth or for its operation during glucose and pyruvate breakdown. The data thus far do not permit a clear statement describing this respiratory mechanism. The presence of such a mechanism is an obligately anaerobic organism, incapable of growth in the presence of oxygen, poses an interesting problem.

Some considerations in the use of the soil perfusion apparatus for microbiological studies. LLOYD R. FREDERICK, Purdue University.—An adaption of the Audus modification of the soil perfusion technique used by Lees and Quastel is described in detail.

Some advantages of the technique are as follows: the soluble and gaseous products of transformations by a heterogenous population may be determined without disturbing the soil sample; the gas used may be controlled; there is very little change in moisture content; additions to the system can be made readily.

Some of the disadvantages are as follows: it is very difficult to use soils in which there are no stable particles larger than 0.25 mm. diameter; studies can be made only under nearly saturated conditions; channels develop which may cause areas that are not in equilibrium; some microbial growth may take place in the perfusate. These difficulties are minimized when 1 — 5 mm. table aggregates are used and the rate of perfusing is fairly rapid with a high ratio of air to water.

This technique is valuable in the study of various factors on the release of soluble materials and the transformation of compounds by microorganisms. Pure cultures can be obtained from the enriched soil. In our studies the oxidation of sulfur caused more manganese to become soluble and the resulting low pH prevented a reversion to the insoluble form.

A comparison of three media used at the Indiana State Board of Health in culturing for tubercle bacilli. C. F. HILL and S. R. DAMON, Indiana State Board of Health.—Two thousand diagnostic specimens, including sputum, gastric washings, urine, and spinal fluid, were cultured for tubercle bacilli in the laboratory of the Indiana State Board of Health. The media used were Jensen's modification of Lowenstein's

formula, Frobisher's modification of Petragnani's formula, and Peizer's Medium.

Special attention was given to the following: 1. Which medium yielded the largest number of recoveries; 2. Which medium gave earliest growth; 3. What combinations of media appear most profitable from the standpoint of total recoveries; 4. Which medium is least satisfactory because of overgrowth by contaminants; 5. Productivity with relation to the length of incubation period.

The results indicated that: 1. Lowenstein's medium was the most satisfactory; 2. Lowenstein's medium gave earliest growth; 3. Lowenstein's and Peizer's media made the best combination; 4. Overgrowth by contamination was greatest on Petragnani's medium; 5. Cultures should be observed at least six weeks.

Use of new microtechniques for bacterial identification. L. S. McCLUNG and E. D. WEINBERG, Indiana University.—A new type of micro method for the rapid identification of biochemical abilities of bacteria is described. The abilities include fermentation of carbohydrates; decomposition of amino acids; hydrolysis of proteins, polysaccharides and lipids; and reduction of inorganic salts.

Whereas previously described rapid methods allow quick multiple action of the culture, this method involves the addition of large, washed inocula to preheated tubes or plates containing substrate and indicator but no other nutrilites. The omission of nutrilites prevents extensive cell multiplication; thus the visible indicator changes presumably result from the activities of cells contained in the inoculum rather than from variants that arise and further multiply in the presence of the substrate.

In carbohydrate fermentation tests of this type, rapid indicator changes (within 15-30 minutes) reflect the activities of constitutive enzymes; slow indicator changes (2-4 hours) reflect the activities of adaptive enzymes. Prior growth of the cells in the presence of the substrate converts slow indicator changes to rapid changes.

On the chemical nature of the Rh factor. MERWIN MOSKOWITZ, Purdue University.—The stability of the Rh factor in human red cell stroma has been tested after being treated with the following agents: trypsin, guanidine, papain, hyaluronidase, *Clostridium welchii* Type A toxin, ultraviolet irradiation, and pyridine. All these agents, with the exception of hyaluronidase, destroyed the Rh factor. These experiments lend support to the hypothesis that the Rh factor is of protein nature, or else is intimately associated with a protein component in the red cell.

Preliminary studies on a cell-free amylase of *Bacillus sterarothermophilus ATCC 7954*. EGON STARK and P. A. TETRAULT, Purdue University. —The isolation of bacterial, cell-free, starch saccharifying enzymes from the medium at 70°C is described (J. B. 62: 247, 1951). A crude enzyme preparation obtained and tested at 65°C for 4 hours saccharified 1 per

cent soluble starch strongly, 0.5 per cent dextrin weakly and 0.5 per cent maltose not at all at pH 5.5 and 8.5 respectively. The following data are preliminary and indicative rather than characteristic. Saccharification proceeded slowly over a wide range of temperature (25°C-95°C) and pH (2.5-11). Optimum temperature 65-75°C; optimum pH 5-7. Better activities above 65°C and below pH 7. Glucosidases acting strongly at very alkaline pH cannot be excluded. Limits of conversion for cell-free enzyme 52-58 per cent, in presence of cells 55-77 per cent. Sixty per cent arbitrarily selected for calculations. Universal buffer (borate, acetate, monosodium phosphate) better than Sorensen's phosphate buffer. Calcium carbonate depressed saccharification of the fermentation medium. Methods and their shortcomings are discussed. Results are shown on slides.

The effect of subfreezing temperatures on pathogens. R. W. SQUIRES and S. E. HARTSELL, Purdue University.—Cell suspensions of *Micrococcus pyogenes var. aureus, Escherichia coli,* #7006, and *Salmonella aertrycke* were quick frozen at the stage of physiological youth and stored at—9°C. from one to fourteen days. Growth curves and characterizing biochemical reactions were determined before freezing and immediately after defrosting of each organism. Fermentation studies and other differential tests were determined by using microtechniques. Growth curves were plotted from turbidimetric data.

Results indicated that, in a few instances, subfreezing temperatures contribute to the acquisition of certain biochemical characteristics. After defrosting, *M. aureus* was observed to ferment xylose, raffinose (with acid, but no gas) and to give a positive test for acetyl methyl carbinol. These changes, observed consistently, do not remain stable in succeeding generations. No significant variations were observed for *E. coli* and *S. aertrycke.*

Turbidimeteric data for defrosted cells indicated that subfreezing temperatures may contribute to some deviations in the growth curve and to an increase in the lag phase. The growth curve for *S. aertrycke* was observed to depart noticeably from that of the control as the time of storage was lengthened. The forms of the growth curve for *M. aureus* and *E. coli* were not altered at the storage times studied.

The lag phase of all species appeared to be a function of the storage period. As the time of storage increased, the longer the refrosted cells remained in the lag phase. The time required for refrosted cells to initiate growth (the recovery period) seemed to be independent of the size of the inoculum employed. Light and dense suspensions of defrosted cells required similar lag times before the initiation of growth.

BOTANY

Chairman: W. G. Gambill, Wabash College

H. R. Youse, De Pauw University, was elected chairman for 1952.

ABSTRACTS

Hybridization between *Aster sagittifolius* and *A. Shortii*. Charlotte Jo Avers, Indiana University.—A biosystematic study of several species of closely-related asters was undertaken in 1949. The present report includes a portion of the results involving only two of the eight species under consideration.

Studies of herbarium specimens and field observations of *Aster sagittifolius* and *A. Shortii* revealed a great variation in the morphology of the two species, some of which might be due to hybridization between them. Crosses were made in 1950 and the seeds planted in the greenhouse that winter. Many of the hybrids bloomed in the fall of 1951 and appear to be highly fertile. The hybrids are intermediate in morphology although there seems to be a greater tendency for *Aster sagittifolius* characters to dominate. Backcrosses and selfings are being made now.

The chromosome number of these two species in southern Indiana is n = 18 with no irregularities at meiosis discernible. The artificial hybrids also show perfect pairing at meiosis which is a strong indication of the close relationship between the two parent species.

Complications in the variation patterns within these species are also introduced due to hybridization with other species in this group, all of which have the basic chromosome number of 9 or 18.

Discovery of the function of the cups of *Polyporus conchifer*. Harold J. Brodie. Indiana University.—The cup-shaped structures produced by the bracket fungus *Polyporus conchifer* are not sterile as has been assumed but are splash-cups from which oidia are thrown to a distance of four feet by raindrops. New fruit bodies develop during late summer, the cup part developing first. Oidia form in the cups in dark-colored granular masses. The jelly in which the oidia are embedded swells when wetted by rain. The cup becomes filled with a suspension of oidia which, when splashed out by raindrops, germinate and produce dikaryotic mycelium. Later in the season, the flat pore-bearing pileus grows out from one rim of the cup and discharges basidospores. During winter, the flat pileus weathers away from the cup.

Sexuality and taxonomic studies in the Bird's Nest Fungi of the genus *Nidula*. Harold J. Brodie. Indiana University.—Four species only are known in the genus *Nidula* all apparently restricted to cool countries or to cool regions in warm countries. *N. candida* and *N. micro-*

carpa are found along the northwest coast of North America. Both fungi have been studied in single spore culture for the first time. They display tetrapolar heterothallism and four major differences in the growth habits of their mycelia. The mycelia of *Nidula* bear a closer resemblance to those of *Crucibulum* and *Nidularia* than to those of *Cyathus*. *Nidula emodensis* from the Himalayas is probably not a distinct species but is the same as *N. microcarpa*. *Nidula macrocarpa* from South America is very different from any other known species. The tropical forms have not been cultured as yet.

Iron deficiency in Pin Oak. I. W. CARPENTER, JR. Purdue University. —*Quercus palustris*, Pin Oak, normally grows only on acid soils, and when planted on calcareous soils often develops iron deficiency symptoms. The symptoms of iron deficiency in Pin Oak are recognized by a yellowing chlorosis of the new leaves, while the mature leaves remain green. A laboratory experiment was carried out on young Pin Oak seedlings to study the effect of pH on the availability of iron. Four concentrations of iron were used at pH levels of 5.0 and 7.0. It was found that at pH 7.0 a nutrient solution containing ten times the normal concentration of iron produced chlorosis. At pH 7.0 chlorosis was acute in a solution containing 1 ppm of iron, while the same solution produced normal plants at pH 5.0. The chlorotic condition of deficient leaves was corrected by painting the leaves with a 3% solution of ferrous sulphate. Iron deficient trees on the Purdue campus were sprayed with the same solution and the chlorotic condition of their leaves was corrected by this treatment.

Cladophora balls collected in Steuben County, Indiana.[1] FAY KENOYER DAILY, Butler University.—In June this last summer while Mr. Daily and I were collecting in the northeastern part of Steuben County, Indiana, we stopped at Long Lake where we found some "Cladophora balls" washed out on the shore and in shallow water. These are hemispherical growths about one and one-half to two centimeters in diameter and are formed from intertwining algal filaments of a felt-like nature. Slides show the macroscopic appearance of "Cladophora balls" and the microscopic nature of the algal filaments of which they are composed.

The mode of growth, habitat, classification and literature concerning collections in the United States are given.

A qualitative study of the phytoplankton of the Lagoon, Shades State Park, Montgomery County, Indiana: A preliminary report.[2] W. A. DAILY, Lilly Research Laboratories, and JACK S. MCCORMICK, Butler University.—This report embraces the period of time from June 12 through August 31, 1951 and is based upon 43 collections. Eighty genera representing five classes (Bacillariophyceae, Chlorophyceae,

[1] To be published in the Butler Univ. Bot. Stud.

[2] To be published in the Butler Univ. Bot. Stud. Vol. X.

Chrysophyceae, Dinophyceae and Myxophyceae) have so far been recorded.

Factors affecting the "waterlogging" of excised sunflower roots cultivated in liquid media. C. W. HAGEN, JR., Indiana University.—The intercellular spaces of excised sunflower roots cultured in White's solution become flooded with liquid after a variable number of weekly transfers. The "waterlogged" roots remain viable but exhibit an altered growth pattern and do not revert spontaneously to the ventilated condition. The probability of flooding of the intercellular spaces increases with the number of weekly transfers the meristem has experienced and also with the amount of growth accomplished during the preceding transfer interval. Waterlogging can be induced by infiltrating the roots with medium under reduced pressure or by growing them in media containing indole-acetic acid. Waterlogged roots can be recovered as ventilated roots by culturing for one week on media solidified with 3% agar.

Quadrat study of fifteen stands in the Early Wisconsin Drift Plain. J. JOHANNA JONES, Butler University.—Woody and herbaceous plants of fifteen stands within the Early Wisconsin Drift Plain are presented in tabular form. *Acer saccharum* and *Fagus grandifolia* are major dominants; *Ulmus americana* and *Fraxinus americana* are present in abundance. Varying percentages of other mesophytic species are present in all cases. Seventy-one woody species and more than one hundred herbaceous species are recorded. Woody and herbaceous species are correlated with climatic and edaphic conditions.

A predaceous fungus, *Sommerstorffia spinosa*. J. S. KARLING, Purdue University.—*Sommerstorffia spinosa* is a species of the family Saprolegniaceae which captures rotifiers on specialized pegs and devours their content to produce zoosporangia and zoospores. So far, it has been reported only twice in the literature, once from Sofia, Bulgaria by Arnaudow in 1923 and again from Massachusetts by Sparrow in 1929. The author has found it on numerous occasions in soils of Indiana. Its thallus consists of short stiff tubular branches terminated by tapering blunt pegs which contain a highly refractive and adhesive substance. When rotifiers feed on these pegs they are held fast and are unable to pull away. The pegs soon grow into the animal's body, absorb its content and eventually develop into zoosporangia. The latter form laterally biflagellate, hetercont, reniform zoospores which give rise in turn to predaceous sporelings. These capture additional rotifiers and soon develop into mature thalli. Sexual reproduction consists of the formation of oogonia on short septate branches, each bearing a single egg which develops into a parthenogenic oospore.

Additional spermatophytes, mosses, and lichens of the Grants (N. M.) lava bed. ALTON A. LINDSEY, Purdue University.—A volcanic area of Tertiary and Recent age covers 220 square miles in west-central New Mexico. The rather small flora includes xerophytes, mesophytes, and hydrophytes, reflecting the wide range of habitat types, such as ice caves, volcanic cones and craters, and permanent ponds in lava. The

latter are unknown elsewhere in North America. The plant species considered most significant ecologically were discussed in a recent paper.[1]

Twenty additional spermatophytes, including *Anthericum torreyi, Aster arenosus, Buchloe dactyloides, Koeleria cristata, Monarda pectinata, Opuntia arborescens, Ranunculus scleratus, Salvia reflexa,* and *Vitis arizonica,* bring the species of this group identified from the lava area to 122.

The 33 species of Bryophyta that were found include two genera of liverworts. Twenty-one moss genera are represented. The moss species hitherto unreported are *Brachythecium erythorrhizon, Bryum cuspidatum, Coscinodon calyptratus, Dicranoweisia cirrata, Eurhynchium diversifolium, Grimmia ovalis, Mnium serratum, Neckera pennata,* and *Paraleucobyrum longifolium.*

Additional lichens, bringing the total identified to 22 species, are *Dermatocarpon miniatum* var. *fulvofuscum, Parmelia amableana, Parmelia caperata* var. *subglauba,* and *Usnea scabiosa.*

A taxonomic and cytogenetic study of four perennial sunflowers. ROBERT LONG, Indiana University.—Various strains of *Helianthus grosseserratus, H. Maximiliana, H. giganteus,* and *H. Kellermanni* were grown in the experimental garden at Indiana University. The haploid chromosome number was found to be seventeen in all four species as previously reported. Artificial hybrids between *H. grosseserratus* and *H. Maximiliana, H. grosseserratus* and *H. giganteus,* and *H. grosseserratus* and *H. Kellermanni* were produced. The hybrids in general were intermediate between the parental species, showed few abnormalities at meiosis, and were rather highly fertile. The four species appear to be closely related from both morphological and genetic standpoints. Herbarium specimens of these species were also examined and it appears possible that hybridization may be responsible for some of the variation encountered in nature.

The vascular flora of the Ross Biological Reserve. CHESTER W. MILLER and A. T. GUARD, Purdue University.—The Ross Biological Reserve is a tract of land consisting of approximately fifty-five acres. It is largely woodland and old fields, both of which had been grazed for many years.

All domestic animals have now been removed from the area and it is the plan to allow it to remain undisturbed except by natural influences.

With this plan in mind it was considered important to have a careful study of the plants growing there at the time of the change.

The vascular flora during the 1950 growing season was found to consist of 319 species in 227 genera and representing 84 families. Of these 43 were introduced species from countries other than the United States.

Inexpensive models and lantern slides for teaching plant science. S. N. POSTLETHWAIT, G. B. CUMMINS, G. A. GRIES, J. H. LEFFORGE, and

[1] Lindsey, Alton A. 1951. Vegetation and habitats in a southwestern volcanic area. Ecological Monographs 21:227-253.

FOREST W. STEARNS, Purdue University.—One of the most difficult concepts for beginning botany students to grasp is that of the three dimensional structure of a plant cell. The array of teaching aids usually available to teachers, i.e. slides, diagrams, drawings, and pictures, are helpful but leave much to the imagination of the student. A few professionally produced models are available. However, the cost is frequently prohibitive and the models often do not illustrate the desired concept. A method has been devised whereby a variety of models can be prepared inexpensively from sheet plastic and without the use of elaborate equipment.

Lantern slides can be prepared rapidly and cheaply using sheet plastic and india ink and colored dye inks. These slides are especially useful in that they can be used in lighted rooms thus allowing the student to take notes during the discussion. Diagrammatic types of illustrations are particularly adaptable to reproduction on plastic and are a valuable supplement to photographic slides.

The forest primeval of Indiana as recorded in the original United States Land Survey. J. S. POTZGER, Butler University.—The study is based on a tabulation of all stems of witness trees listed by the surveyors in the U. S. Land Survey, dating from 1799 in southern Indiana to 1839 in northern Indiana. The important species in the mixed mesophytic forest cover and the oak-hickory (indicating drier habitats) are presented in terms of percentages of the total number of stems listed for a given township. Only the upland species of ash and oak are included in the percentages. Except for the nine northwestern "prairie" counties, a comparatively narrow strip along the Indiana-Michigan boundary and a few counties in the southwestern corner of the state, where oak or oak-hickory predominate, the primeval forest was chiefly of the mixed mesophytic type in which beech, several species of ash and sugar maple play the major role. In some townships beech represented 69 to 70 per cent of the trees listed, while sugar maple seldom attained an abundance of 20 per cent.

Preliminary study of the effect of topography on the distribution of sugar and black maples and their intermediate forms. CHARLES W. REIMER, Michigan State College.—The technique of Dansereau and Desmarais[1] was used for characterizing maple leaves collected in three areas (two collections in Indiana and one in Michigan). Analysis of the collection from the Michigan woodlot revealed that a total of 11% of the leaves were to be considered as intermediate forms between *Acer saccharum* (Marsh) and *A. nigrum* (Michx). In the two Indiana woodlots totals of 36% and 46% were recorded as intermediate forms. This would suggest that hybridization is more pronounced in the Indiana woodlots.

In all three areas introgression appears in favor of *A. saccharum* although this tendency is more striking in the Michigan woodlot. The

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[1] Dansereau, P. & Yves Desmarais. Introgression in Sugar Maples II. Amer. Midl. Nat. **37**:146-161. January, 1947.

A. nigrum-like specimens including the "pure" forms are all restricted to the lowland, a slightly cooler, more shaded, and possibly more hydric habitat. The habitat for *A. saccharum*-like specimens seems not to be so select, but of the three collection sites (viz. lowland, slope, upland) they appear in greater abundance on the uplands.

Genera are listed in the order used in Deam: Flora of Indiana, and species are given alphabetically within the genera. Symbols following the county in which specimens were collected indicate the herbaria in which confirming specimens have been deposited. Entities listed for the first time for the state are given in bold face followed by literature references and name of collector. Nomenclature is in accordance with that of Gray's Manual of Botany, 8 ed., 1950.

Specimens for entities listed below have been placed in one or more of the following herbaria and have been collected by the following collectors: Ball State Teachers College (BS): Mrs. Marion Rector; Butler University (B); Charles C. Deam, Ray C. Friesner, J. Johanna Jones, Jack McCormick, J. E. Potzger, and F. A. Swink; Deam Herbarium (D); Charles C. Deam and R. C. Friesner; Franklin College (Fr): Naomi Mullendore Hougham; Wabash College (W): A. R. Bechtel, W. W. Chipman, and D. B. Ward.

The Committee maintains a card file showing the published distribution of each taxonomic entity within the state. Botanical workers needing such information may obtain distribution maps of any entity recorded in the Flora, or subsequently added in these reports, by requesting same from the secretary of this committee.

Taxonomic Entities

Botrychium dissectum, Hendricks (B). *B. d.* f. *obliqunm,* Delaware (B), Madison (B). *Cystopteris fragilis* v. *protusa,* Boone (B), Clinton (B), Delaware (B). *Onoclea sensibilis,* Boone (B), Clinton (B). *Polystichum acrostichoides,* Clinton (B.) *Athyrium filix-femina* v. *asplenioides,* Boone (B). *A. pycnocarpon,* Union (B). *Adiantum pedatum,* Shelby (B). *Dennstaedtia punctilobula,* Fountain (B). *Equisetum hyemale* v. *intermedium,* Montgomery (B).

Taxodium distichum, Gibson (B). *Bromus inermis,* Fountain (B), Montgomery (B). *B. latiglumis,* Dearborn (B). *B. secalinus,* Parke (B). *Vulpia octoflora* v. *tenella,* Montgomery (W). *Poa compressa,* Dearborn (B). *Dactylis glomerata,* Fountain (B), Parke (B). *Elymus villosa,* Ripley (B). *E. virginicus,* Dearborn (B). *Hystrix patula* v. *bigloviana,* Owen (B). *Agrostis alba,* Dearborn (B), Switzerland (B). *A. hiemalis,* Fountain (B). **Phleum pratense** f. **viviparum** (S. F. Gray) Louis-Marie. Gray Man. 8 ed. p. 165. Montgomery (B). Collected by Jack McCormick. *Aristida longespica,* Switzerland (B). *Paspalum circulare,* Switzerland (B). *Panicum clandestinum,* Fountain (B). P. **dichotomiflorum** v. **geniculatum** (Wood) Fern. Gray Man. 8 ed. p. 206. Montgomery (B). Collected by Jack McCormick. *P. dichotomum,* Fountain (B). *P. huachucae,* Dearborn (B). *P. linearifolium,* Dearborn (B). *Setaria viridis,* Fountain (B).

Arisaema atrorubens f. *viride*, Greene (B). *A. a.* f. *zebrina*, Greene (B). *A. dracontium*, Clinton (B), Hendricks (B). *Commelina communis*, Parke (B). *Uvularia grandiflora*, Union (B). *Allium canadense*, Fayette (B). *A. tricoccum*, Shelby (B), Union (B). *A. vineale*, Henry (B). *Smilacina racemosa* v. *cylindrata*, Clinton (B), Madison (B), Union (B). *Polygonatum pubescens*, Boone (B), Clinton (B), Madison (B), Union (B). *Smilax lasioneura*, Boone (B), Madison (B). *Hypoxis hirsuta*, Delaware (BS). *Dioscorea villosa*, Fountain (B), Shelby (B). *Sisyrinchium angustifolium*, Henry (B). *Orchis spectabilis*, Shelby (B). *Liparis lilifolia*, Union (B). *Aplectrum hiemale*, Fountain (B).

Populus deltoides, Fountain (B). *Carya cordiformis*, Boone (B) *C. glabra*, Fountain (B). *C. laciniosa*, Fountain (B). *C. ovalis*, White (B). *C. ovata*, Harrison (B). *Ostrya virginiana* f. *glandulosa*, Boone (B), Clinton (B), Montgomery (B). **Fagus grandifolia** f. **pubescens** Fern. & Rehd. Gray Man. 8 ed. p. 540. Hendricks (B), Henry (B), Randolph (B), Ripley (B). Collected by R. C. Friesner and Johanna Jones. *Quercus alba*, Adams (B). *Q. bicolor*, Adams (B), Boone (B), Fountain (B). *Q. coccinea*, Cass (B), Lagrange (B), Montgomery (W). *Q. c.* v. *tuberculata*, Elkhart (B, D). *Q. imbricaria*, Lake (B). *Q. macrocarpa*, Fountain (B). *Q. palustris*, Boone (B), Fountain (B). *Q. shumardii*, Fountain (B), White (B). *Ulmus rubra*, Fountain (B). *Celtis occidentadis*, Henry (B). *C. o.* v. *pumila*, Fountain (B). *Urtica dioica* v. *procera*, Delaware (BS). *Laportea canadensis*, Delaware (BS). *Boehmeria cylindrica*, Henricks (B), Union (B).

Asarum canadense, Madison (B). *Aristolochia serpentaria*, Boone (B), Clinton (B), Henry (B), Union (B). *Rumex obtusifolius*, Fountain (B). *R. verticillatus*, Clinton (B). *Polygonum aviculare*, Fountain (B), Parke (B). *Tovara virginiana*, Fountain (B). *Fagopyrum sagittatum*, White (B). *Chenopodium album*, Delaware (BS), Fountain (B). *Antriplex patula*, Parke (B). *Kochia scoparia*, Lake (B). *Amaranthus hybridus*, Delaware (BS). *Mollugo verticillatus*, Fountain (B). *Stellaria media*, Marion (B). *Cerastium nutans*, Daviess (B). *C. vulgatum* v. *hirstum*, Greene (B), Henry (B), Union (B). *C. v.* v. *h.* f. *glandulosum*, Greene (B). *Sagina decumbens*, Greene (B). *Arenaria serpyllifolia*, Daviess (B), Greene (B), Shelby (B). *Silene antirrhina* f. *apetala*, Jasper (B). *S. stellata* v. *scabrella*, Fountain (B). *S. virginica*, Union (B). *Lychis alba*, Madison (B). *Dianthus armeria*, Henry (B).

Hydrastis canadensis, Clinton (B), Randolph (B), Union (B). *Anemone virginiana*, Fountain (B). *Anemonella thalictroides*, Hendricks (B). *Hepatica acutiloba*, Boone (B). *Ranunculus abortivus*, Daviess (B) *R. acris*, Henry (D, B). *R. hispidus*, Hendricks (B). *R. sceleratus*, Wells (B, BS). *R. septentrionalis*, Boone (B), Daviess (B). *Menispermum canadense*, Boone (B). *Asimina triloba*, Clinton (B). *Lindera benzoin*, Clinton (B), Delaware (B), Fountain (B), Madison (B). *Sanquinaria canadensis*, Boone (B), Clinton (B). *Lepidium campestre*, Henry (B). *L. densiflorum* v. *typicum*, Clinton (B). *L. virginicum*, Franklin (B). *Sisymbrium altissimum*, Franklin (B). *S. officinale*, Delaware (B), Fayette (B). *S. o.* v. *leiocarpum*, Fountain (B), Shelby

(B). *Arabidopsis thaliana,* Daviess (B), Greene (B) *Brassica kaber* v. *pinnatifida,* Montgomery (W). *Barbarea vulgaris* v. *arcuata,* Henry (B). *Rorippa islandica* v. *fernaldiana,* Fountain (B), Owen (B). *Capsella bursa-pastoris,* Daviess (B.) *Draba brachycarpa,* Daviess (B), Greene (B). *Draba verna,* Daviess (B). Greene (B). *Descurainia pinnata* v. *brachycarpa,* Daviess (B), Greene (B). *Sibara virginica,* Daviess (B).

Penthorum sedioides, Fountain (B), Owen (B). **Mitella diphylla** f. **oppositifolia,** (Rydb.) Rosend. Gray Man. 8 ed. p. 744. Montgomery (B). Collected by R. C. Friesner. *Hydrangea arborescens,* Fountain (B). *Rubus allegheniensis,* Montgomery (B). *R. flagellaris,* Montgomery (B). *R. occidentalis,* Parke (B). *R. o.* f. *pallidus,* Hamilton (B). *Potentilla norvegica,* Fountain (B), Parke (B). *P. recta,* Shelby (B). *P. simplex* v. *typica,* Clinton (B), Union (B). *Geum laciniatum,* Henry (B), Wayne (B). *G. virginianum,* Parke (B). *Agrimonia gryposepala,* Clinton (B). *A. pubescens,* Boone (B). *A. rostellata,* Clinton (B). *Rosa carolina,* Union (B). *Prunus americana,* Daviess (B, D), Greene (B, D), Ripley (D). *P. angustifolia,* Boone (B), Hendricks (B). **Ribes cynosbati** f. **inerme** Rehd. Gray Man. 8 ed. p. 749. Montgomery (B). Collected by Jack McCormick.

Gleditsia triacathos, Delware (BS). *Medicago lupulina,* Marion (B), Wayne (B). *M. sativa,* Shelby (B). *Melilotus alba,* Hamilton (B.) *M. officinalis,* Hamilton (B), Wayne (B). *Trifolium hybridum* v. *elegans,* Fountain (B), Montgomery (B), Shelby (B). *T. pratense,* Shelby (B), White (B). *T. procumbens,* Lake (B). *T. repens,* Parke (B), Shelby (B). *Desmodium glutinosum,* Hendricks (D). **D. g.** f. **chandonnetti** (Lunell) Schub. Gray Man. 8 ed. p. 918. Fountain (B). Collected by Jack McCormick. *D. nudiflorum,* Fountain (B). **D. n.** f. **foliolatum** (Farwell) Fassett. Gray Man. 8 ed. p. 918. Montgomery (B). Collected by Jack McCormick. **D. n.** f. **personatum** Fassett. Gray Man. 8 ed. p. 918. Montgomery (B). Collected by Jack McCormick. *D. paniculatum,* Clinton (B). **Lespedeza cuneata** (Dumont) G. Don. Gray Man. 8 ed. p. 927. Crawford (B), Montgomery (B), Parke (B). Collected by R. C. Friesner, Johanna Jones, and Jack McCormick. *L. intermedia,* Montgomery (W). *L. stipulacea,* Fountain (B), Montgomery (B). *Amphicarpa bracteata,* Fountain (B), Hendricks (B).

Geranium maculatum, Clinton (B). *Oxalis europea* f. *cymosa,* Montgomery (B). *O. e.* f. *villicaulis,* Fountain (B). *Linum medium* v. *texanum,* Fountain (B). *Xanthoxylum americanum,* Fountain (B). *Croton monanthogynus,* Henry (B). *Euphorbia marginata,* Montgomery (B). *Floerkea proserpinacoides,* Hendricks (B). *Rhus radicans* f. *negundo,* Hendricks (B), Shelby (B). *Euonymus atropurpureus,* Fayette (BS). **Acer rubrum** f. **tomentosum** (Desf.) Dansereau. Gray Man. 8 ed. p. 987. Fountain (B). Collected by Jack McCormick. *Impatiens pallida,* Fountain (B). *Parthenocissus quinquefolia,* Clinton (B). *Abutilon theophrasti,* Delaware (BS). *Malva neglecta,* Delaware (BS). *Sida spinosa,* Delaware (BS). *Hibiscus trionum,* Fountain (B), Jay (D). *Hypericum mutilum,* Shelby (B). *Viola pensylvanica,* Boone (B), Fountain (B), Hendricks (B), Union (B). *V. p.* v. *leiocarpa,* Boone (B),

Clinton (B,), Fountain (B), Henry (B), Madison (B), Randolph (B), Union (B). *V. papilionacea*, Hendricks (B). *V. striata*, Boone (B). *V. triloba*, Randolph (B).

Oenothera perennis, Montgomery (W). *Oe. biennis* v. *pycnocarpa*, Parke (B). *Circaea quadrisulcata* v. *canadensis*, Madison (B). *Panax quinquefolius*, Shelby (B), Union (B). *Sanicula canadensis* v. *typica*, Clinton (B). *Eryngium yuccifolium*, Montgomery (W). *Osmorhiza claytoni*, Boone (B), Shelby (B). *O. longistylis*, Madison (B). *Erigenia bulbosa*, Henricks (B). *Cryptotaenia canadensis*, Clinton (B). *Thaspium trifoliatum* v. *flavum*, Union (B). *Pastinaca sativa*, Shelby (B), Wayne (B). *Daucus carota* f. *eupurpurata*, Parke (B). *Cornus drummondii*, Daviess (B). *C. florida*, Clinton (B). *C. obliqua*, Parke (B). *Nyssa sylvatica* v. *caroliniana*, Adams (D, B). *Chimaphila maculata*, Fountain (B). *Lysimachia lanceolata*, Montgomery (B). **Diosyros virginiana** v. **pubescens** (Pursh) Dippel. Gray Man. 8 ed. p. 1145. Montgomery (B). Collected by Jack McCormick. *Fraxinus pennsylvania* v. *subintegerrima*, Jay (D). *Apocynum cannabinum*, Delaware (B). *Asclepias incarnata*, Delaware (BS).

Ipomoea hederacea, Delaware (BS). *Phlox divaricata*, Hendricks (B). *Polemonium reptans*, Boone (B). *Hydrophyllum appendiculatum*, Greene (B). *H. canadense*, Fountain (B). *H. macrophyllum*, Hendricks (B). *H. virginianum*, Clinton (B), Madison (B). *Phacelia bipinnatifida*, Greene (B). *P. purshii*, Daviess (B). *Lithospermum arvense*, Daviess (B), Ripley (D). *Verbena canadensis*, Blackford (BS), Delaware (BS). *V. urticifolia* v. *leiocarpa*, Fountain (B). *Scutellaria incana*, Fountain (B). *Nepeta cataria*, Delware (BS), Fountain (B). **Prunella vulgaris** f. **albiflora** (Borgenh.) Britt. Gray Man. 8 ed. p. 1225. Montgomery (B). Collected by Jack McCormick. *Physostegia virginia* v. *speciosa*, Daviess (B). *Stachys tenuifolia*, Delaware (BS). *Monarda clinopodia*, Fountain (B). *Blephilia hirsuta*, Fountain (B). *Pycnanthemum flexuosum*, Hamilton (B). *Lycopus rubellus*, Owen (B). *L. virginicus*, Hendricks (B), Montgomery (B). *Mentha arvensis* v. *villosa* f. *glabrata* Montgomery (B). *M. spicata*, Delaware (BS). *Collinsonia canadensis*, Clinton (B), Shelby (B). *Perilla frutescens* v. *crispa*, Fountain (B), Johnson (Fr).

Physalis subglabrata, Delaware (BS). **Solanum carolinense** f. **albiflorum** Benke. Gray Man. 8 ed. p. 1254. Fountain (B), Montgomery (B). Collected by Jack McCormick, *Datura stramonium*, Delaware (BS). *Linaria vulgaris*, Henry (B). *Chaenorrhinum minus*, Henry (B), Shelby (B). *Penstemon digitalis*, Henry (B). *Veronica arvensis*, Greene (B). *Conopholis americana*, Fountain (B). *Epifagus virginiana*, Hendricks (B). *Ruellia humilis* v. *expansa*, White (B). *R. h.* v. *frondosa*, Henry (B). *Phryma leptostachya*, Boone (B), Fountain (B). *Plantago aristata*, Fountain B. *P. indica*, Lake (B). *P. virginica*, Daviess (B). *Houstonia caerulea*, Montgomery (W). *H. purpurea*, Union (B). *Galium circaezans* v. *hypomalacum*, Boone (B), Clinton (B), Madison (B). *G. mollugo*, Wayne (B). *G. obstusum*, Boone (B), Clinton (B). *G. triflorum*, Boone (B), Hendricks (B). *Viburnum molle*, Crawford (B). *Triosteum aur-*

antiacum, Boone (B). *Lonicera canadensis,* Steuben (D, B). **Campanula americana v. illinoense** (Fresn.) Farwell. Gray Man. 8 ed. p. 1352. Montgomery (B). Collected by Jack McCormick. *Specularia perfoliata,* Union (B). *Lobelia cardinalis,* Shelby (B). *L. spicata* v. *originalis,* Henry (B).

Vernonia altissima, Delaware (BS). *V. missurica,* Greene (B). *Eupatorium altissimum,* Greene (B). *E. purpureum,* Shelby (B). **E. rugosum v. tomentellum** (Robbins) Blake. Gray Man. 8 ed. p. 1369. Montgomery (B). Collected by Jack McCormick. *Kuhnia eupatorioides* v. *corymbulosa,* Montgomery (B). *Solidago ceasia,* Boone (B). *S. c.* **f.** *axillaris,* Randolph (B). *S. flexicaulis,* Boone (B), Shelby (B). *S. graminifolia* v. *nuttallii,* Fountain (B). *S. Xulmicaesia,* Montgomery (B). **Aster azureus f. laevicaulis** Fern. Gray Man. 8 ed. p. 1424. Benton (B), Cass (B), Elkhart (B), Jasper (B), Lake (B), La Porte (B), Newton (B), Porter (B), Starke (B), White (B). Collected by Floyd Swink, R. C. Friesner, Charles C. Deam, and J. E. Potzger. *A. cordifolius,* Boone (B), Clinton (B). *A. lateriflorus,* Boone (B), Clinton (B), Fountain (B), Hendricks (B). *A. ontarionis,* Clinton (B), *A. pilosus,* Fountain (B). *A. sagittifolius,* Fountain (B). *A. s.* v. *urophyllus,* Whitley (B). *Erigeron annuus,* Wayne (B). *Polymnia canadensis,* Fountain (B). *Ambrosia artemisiifolia* v. *elatior* f. *villosa,* Daviess (B). *Eclipta alba,* Fountain (B). *Rudbeckia hirta,* Parke (B). *R. triloba,* Owen (B). *Helianthus decapetalus,* Boone (B), Jay (D), Randolph (B). *H. divaricatus,* Greene (B). *H. giganteus,* Greene (B). *H. petiolaris,* Delaware (BS). *Actinomeris alternifolia,* Daviess (B). *Coreopsis tripteris,* Greene (B). *Bidens comosa,* Fountain (B). *B. connata* v. *petiolata,* Delaware (BS).

Matricaria matricarioides, Wayne (B). *Artemisia annua,* Fountain (B). *Erechtites hieracifolia* v. *praealta,* Montgomery (B). *Cacalia atriplicifolia.* Fountain (B). *Senecio obovatus,* Fayette (B). *Arctium minus,* Delaware (BS). **Cirsium discolor f. albiflorum** (Britt.) House. Gray Man. 8 ed. p. 1541. Fountain (B). Collected by Jack McCormick. *Cichorium intybus,* Ripley (B). **C. i. f. roseum** Neum. Gray Man. 8 ed. p. 1547. White (B). Collected by Jack McCormick. *Taraxacum erythrospermum,* Montgomery (B). *T. officinale,* Parke (B). *Sonchus asper,* Delaware (BS). *Lactuca canadensis* v. *latifolia,* Fountain (B), Montgomery (B). *L. c.* v. *longifolia,* Clinton (B). *L. c.* v. *typica,* Parke (B). *L. floridana,* Clinton (B), Hendricks (B,) Henry (B), Montgomery (B), Shelby (B), Union (B). *L. f.* v. *villosa,* Hendricks (B), Jay (D), Randolph (B), Union (B). *L. scariola,* Fountain (B). *Prenanthes altissima,* Boone (B), Clinton (B), Fountain (B), Hendricks (B), Henry (B). **P. a. v. cinnamomea** Fern. Gray Man. 8 ed. p. 1562. Montgomery (B). Collected by Jack McCormick.

State Flora Commiteee: CHARLES C. DEAM, *Chairman*
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Higher Fungi of Marion County, Indiana

JOHN O. COTTINGHAM, Indianapolis

This, my fifth report of the Higher Fungi of Marion County, Indiana, contains twelve species, making a total of three hundred sixty-five species thus far found and identified:

Agaricaceae

Agaricus silvatica Schaeff
Amanita rubescens Fr.
Inocybe fibrosa Bres.
Marasmius erythropus Fr.
Pholiota discolor Pk.
Pleurotus lignatilis Fr.
Psathyrella sarcocephala A. H. Smith
Volvaria gloiocephala Fr.

Clavariaceae

Pterula plumosa Schw.

Hydnaceae

Irpex tulipifera Schw.

Ascomycetes

Gyromitra esculenta (Pers.) Fr.
Peziza repanda Wahlb.

Mycophagy

JOHN O. COTTINGHAM, Indianapolis

It has been suggested that I record my experiences and opinions regarding the eating of many species of mushrooms. In doing so I am aware that I may not be contributing much to what has already been written.

I am submitting to The Indiana Academy of Science a number of species, that I have eaten, with my comments regarding their esculent qualities. In determining the taste and flavor I give credit to my wife, who has assisted me many times.

Agaricus campestris Fr., *A. placomyces* Pk., and *A. Rodmani* Pk., are considered among the best although I found *A. Rodmani* much stronger in flavor than the others. *Agaricus silvatica* Schaeff, is milder flavored than the others and is very delicious. It is unfortunate that this species is so rare.

Armillaria mellea Fr., when gathered young and fresh, I find to be fair in flavor but not excellent. This species is soon infested with larvae.

Calvatia cyathiformis Bosc, *C. gigantea* Batsch, and *Lycoperdon pyriforme* Schaeff, are good if you like puff balls but I am not fond of any of them.

Cantharellus cibarius Fr., and *Craterellus cantharellus* Schw., have similar flavors and are among the best.

Clitocybe illudens Sacc. A physician called me late at night, said he had three patients ill of mushroom poisoning and asked me to identify the mushrooms. I found them to be Jack-O-Lanterns as expected. No deaths reported from eating this species. I have not tasted it.

Clitocybe monadelpha Morg., and *C. multiceps* Pk., are good but not excellent.

Claudopus nidulans (Pers.) Pk., I have eaten this species and considered it fair in flavor but a little tough. I know of one couple who ate it and became ill in the night but were well the next day.

Collybia longipes Fr., *C. radicata* Fr., *C. platyphylla* Fr., *C. velutipes* Fr., *C. dryophylla* Bull. One authority said "this genus offers no highly desirable species for the table". It is true that some are very watery but I find, if they are fried dry and brown, that *C. radicata* and *C. dryophylla* are excellent.

Coprinus atramentarius Fr., *C. comatus* Fr., *C. micaceus* Fr., are all very good. They have a nutty flavor and should be sought for and used for food.

Cortinarius michiganensis, Kauff. I have found and eaten this species in quantity and find that, while they are safe to eat, the flavor is almost lacking.

Gyromitra esculenta Pers. There has been a great controversy regarding the edibility of this fungus. We have eaten and enjoyed it. A man called me, described it and wanted to know if it is edible. I told him that one authority said one hundred and sixty people had been killed by eating this mushroom. I also told him that we ate it and that many others have eaten it without bad effect. He called me up later and said he and his friends ate it and loved it and he thanked me for my information. If one hundred and sixty persons died from eating this species, who and where were they and who kept the record? I agree with Güssow and Odell that, if this mushroom is fresh, it will cause no harm.

Hydnum caput-ursi Fr., and *Hericeum (Hydnum) coralloides* S. F. Gray are delicious. We stew them with butter added. *H. repandum* L., is very meaty and has an interesting flavor.

Lactarius piperatus Fr. when fried well is very good.

Lepiota Morgani Pk. I ate a piece the size of a quarter, raw, at 6 o'clock. At nine o'clock I became very ill with pain and vomiting. In about thirty minutes, the symptoms were gone and I was well again. McIlvain, in reporting a similar case, said that, if the mushroom had been cooked, it might not have been poisonous. Many people report that they have eaten this green gilled species with impunity but there is no doubt that it is poisonous to some people, although not fatally. *L. procera* Fr. and *L. americana* Pk., are excellent. *L. naucina* Fr. is one of the best. This beautiful white mushroom looks like the "Destroying Angel," but can be distinguished by the absence of a volva.

Marasmius oreades Fr., called the "Fairy Ring Mushroom" is also excellent. We found a large quantity on the golf course at Wawasee. We dried them and had mushrooms to eat for many weeks.

Morchella. Have eaten every species and find *M. deliciosa* Fr., as the name indicates, to be more tender and delicious than the others. *M. semi-libera* D. C. has a very insipid flavor. I believe the morels to be the most popular of all the wild mushrooms.

Mycena leajana Berk, is very good if fried brown. Otherwise, it is watery. *M. galericulata* Scop. Although often passed up as worthless, on account of its small size, I find it is worth gathering and eating. The flavor is excellent.

Naematoloma (Hypholoma) sublateritium Karsten and *H. appendiculatum* Fr., are very good. They should be fried brown. *H. sublateritium* Fr. is better than some authorities say. I have eaten them for years and have never yet tasted one that was bitter. They can be found until near Christmas and are better when found late, for then they do not become infested.

Pholiota praecox Fr., is very good.

Pleurotus ostreatus Fr. and *P. sapidus* Kalchb. are very delectable. I believe I have eaten more of these than of any other species. October, November, December, are the best months for then they are generally

free from larvae. Have gathered them many times when frozen solid. They can be dried and eaten later.

Pleuteus cervinus Schaeff is rather watery and is soon infested in warm weather but, if fried brown, when fresh, they are very good. Can be found from early spring until late fall.

Polyporous sulphureus Fr. While Gibson and others praise this species very highly, the portions I ate seemed to be almost tasteless, perhaps because they were not so young and tender as they should have been.

Psilocybe connissana Pk., while edible is lacking in fine flavor.

Tricholoma personatum Fr. This large meaty mushroom is one to be sought for and enjoyed. We found a large fairy ring of this species at McCormick's Creek State Park. They have a very fine flavor. I gave some to a friend, who reported to me that he was made ill from eating them but he said "they were creamed," in which case, I believe they were not thoroughly cooked. While some may be eaten raw, I believe most mushrooms should be cooked well done. They should be free from larvae and all old or partially spoiled portions should be discarded.

Growth and Development of Hardwood Seedlings

Daniel DenUyl, Purdue University

Thirty years ago, the Indiana Forest Classification Act, which provided certain tax benefits to woodland owners who excluded domestic livestock from their woods, was enacted. Woodlands entered under this law provide excellent places for the study of the changes that take place in the protected woods. To the botanist, the ecologist, and the forester these protected woods are field laboratories in which plant populations can be studied.

Twenty years ago, a woodland management project was started by the Purdue Agricultural Experiment Station. A series of permanent sample plots were established in some of Indiana's classified and protected woods. One of the objectives was to study the regeneration of the woods following the removal of livestock. As part of the general study, milacre quadrats permanently marked and systematically distributed over the plot, were established.

Previous reports (1) have already shown that the condition of a woods, recognized as a stage of decadence, at the time livestock are excluded, will influence the natural regeneration. The composition of the overhead stand, seed production and dissemination, with all its variables, and the condition of the seedbed, ground cover, etc., all exert an influence. No attempt is being made to show how each influence acts on the tree seedlings but simply to show the results of the action of all site factors in terms of tree seedling establishment and growth under woods conditions.

Remeasurements of the quadrats were made annually for the first 10 year period (1931-1940) and periodically during the period 1941-1950. Although several hundred thousand measurements of tree seedlings have been recorded for the permanent sample plots, this paper presents a selected sample of the results from one woods which has been protected from livestock grazing and fire for 25 years.

Because of the great changes which take place from year to year in the current crop of newly germinated tree seedlings, only those seedlings which survived one season were located, mapped and tagged on each quadrat. It was impossible to get a record of all the seedlings that came into the quadrats. Some seedlings came into the quadrats and died before the annual remeasurements were made while others came in after the annual measurements had been taken.

Seedlings under 6 inches in total height were counted on each quadrat at each remeasurement period and those seedlings over 6 inches in total height were tagged. The development of each tagged tree was followed for 20 years or until the seedling died.

The part of the woods in which the quadrats are located is stocked with 70 trees per acre 6 inches or more in diameter. There are 14 trees, 6 to 10 inches in diameter and 56 are from 11 to 30 inches in

diameter. The species present are shagbark hickory *(Carya ovata)*, bitternut hickory *(Carya cordiformis)*, red oak *(Quercus rubra)*, bur-oak *(Quercus macrocarpa)*, black oak *(Quercus velutina)*, sugar maple *(Acer saccharum)*, silver maple *(Acer saccharinum)*, American elm *(Ulmus americana)*, slippery elm *(Ulmus fulva)*, beech *(Fagus grandifolia)*, and basswood *(Tila glabra)*. In other parts of the woods, other hardwood trees of seed bearing size such as white ash *(Fraxinus americana)*, black ash *(Fraxinus nigra)*, white oak *(Quercus alba)*, and walnut *(Juglans nigra)*, are present.

At the time the quadrats were established the ground cover consisted principally of herbaceous vegetation such as clearweed *(Pilea pumila L.)*, sedge *(Carex sp.)*, and bluegrass *(Poa pratensis L)*. During the past 20 years most all of the clearweed and blue grass have disappeared and only a scattering of sedge can be found in the more open portions of the woods. The woods, in 1931, was classified as a transition stage woods (1), with only a few scattered hawthorn *(Crataegus)*, elm, and black cherry present.

Results

Complete records of sample quadrats are shown in Tables 1, 2 and 3. All of these quadrats are located within the boundaries of a half-acre permanent sample plot.

The quadrat shown in Table I is partly shaded by the canopy of the overhead stand. Two tree seedlings, both under six inches in height, were present when the quadrat was established in 1931. Apparently the black cherry seedling tagged in 1932 was one of the two present in 1931. Basswood and black ash were next to come into the area. Each year some seedlings under six inches in height were recorded and gradually a few seedlings were added to the permanent record. The quadrat record shows how the height growth of seedlings varies from year to year. Some seedlings may be cut off by rodents or be killed back, as illustrated by the black cherry and hophornbeam in the quadrat. Some species come into the area and remain for a comparatively short period of time.

It is apparent from the record that in 1950 basswood seedlings were competing with black ash, black cherry, and hophornbeam. Even though more sugar maple seedlings came into the quadrat than any other species, not one was present in the quadrat in 1950. Hickory and oak, the dominant species in the overhead stand were not represented in the quadrat. At no time during the 20-year period did an oak seedling appear in the quadrat.

The quadrat shown in Table II is located in a partially shaded place where the only competition would come from the overhead stand. Seedlings of hawthorn (Crataegus), American elm, slippery elm, and black cherry *(Prunus serotina)* were tagged in 1931 when the quadrat was established. In addition one red maple and one black ash *(Fraxinus nigra)* seedling were present. A few prickly ash were present but they gradually died out.

TABLE I. Tree Seedlings—A Record of their Establishment and Growth on a 1/1000 Acre Quadrat

Reproduction—over 6″ in total height

Species	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1945	1950
Black Cherry		7	8	10	11	12	18	Cut-off Sprouted				31
Basswood					6	11	21	31	32	39	60	84
Basswood						7	13	18	20	25	36	60
Black Ash						7	7	8	9	14	36	72
Shagbark Hickory							6	10	12	Dead		
Basswood							6	13	15	20	36	48
Sugar Maple							6	4	7	10	Dead	
Hophornbeam							13	22	29	70	—	12
Basswood							8	8	11	Dead		
Black Cherry										10	Dead	
Sugar Maple										7	Dead	
Totals in Numbers Present		1	1	1	2	4	9	9	9	8	6	6

Reproduction under 6″
Number of Seedlings

Species	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940		
Red Maple	1		2									
Black Cherry	1									1		
Sugar Maple		2	2	2	2	2	1	1	5	5		
Black Ash			4									
Basswood				3	1	2	1		3	1		
Hophornbeam				1		2						
Shagbark Hickory				1	1	1						
Slippery Elm										1		
Totals	2	2	8	7	4	7	2	1	8	8		

TABLE II. Tree Seedlings—A Record of their Establishment and Growth on a 1/1000 Acre Quadrat

Species	Reproduction—over 6" in total height											
	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1945	1950
Slippery Elm	14	20	26	28	33	30	35	38	42	42	—	—
Slippery Elm	13	18	34	51	59	75	87	102	120	137	180	216
American Elm	7	12	13	13	19	29	34	39	27	38	—	—
American Elm	7	10	13	14	14	18	26	23	16	20	—	—
American Elm	11	18	24	24	21	29	30	38	38	44	48	—
American Elm	15	18	25	32	32	38	44	47	48	52	52	—
American Elm	10	12	13	14	17	—						
Basswood	7	10	—									
Black Cherry	7	8	10	11	14	15	18	28	31	14	—	—
Crataegus or Hawthorn	18	18	24	31	34	37	31	40	42	26	76	120
Crataegus or Hawthorn	36	36	42	47	50	56	70	84	92	103	—	—
Crataegus or Hawthorn	36	40	49	49	54	57	64	72	75	79	72	72
Crataegus or Hawthorn	40	42	51	64	70	73	74	80	85	93	98	120
Slippery Elm		9	10	11	17	19	24	13	15	10	—	—
Red Oak				7	8	9	9	12	12	10	6	4
Red Oak				7	7	7	10	3	Dead			
Basswood					8	12	19	29	31	30	30	25
Basswood					8	15	18	30	36	39	39	42
Red Oak					8	9	12	10	9	7	7	—
Basswood							15	17	21	23	24	—
Red Oak							11	7	4	5	—	—
Shagbark Hickory								7	7	5	6	—
Totals in Numbers Present	13	14	13	15	18	17	19	20	19	19	12	7

Reproduction under 6″
Number of Seedings

Species	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940		
Black Ash	1											
Red Maple	1											
Sugar Maple		2		3	2	1			1			
Basswood				7	6	5			1	4		
Red Oak				1				1	1			
Shagbark Hickory					1							
American Elm								1				
Totals	2	2		11	9	6	0	2	3	4		

TABLE III. Tree Seedlings—A Record of their Establishment and Growth on a 1/1000 Acre Quadrat

Reproduction—over 6" in total height

Species	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1945	1950
Black Ash	14	14	19	12	14	17	21	23	25	30	30	
Basswood			7	8	9	12	16	24	33	38	65	108
Basswood				6	7	11	14	23	27	22	24	
Basswood				7	8	11	16	24	34	39	72	108
Black Ash					6	7						
Black Ash					8	8	10	13	14	15	48	76
Black Ash					8	8	8	8	10	11	24	
Basswood					6	8	11	14	14	24		
Basswood					7	10	14	25	29	36	50	72
Slippery Elm					9	12	17	23	27	38		
Basswood					8	11	14	23	28	35	84	102
Basswood					12	16	24	27	35	19		
Basswood						8	10	17	22	29	48	54
Basswood						8	11	12	19	22		
Basswood						9	13	17	27	33	60	84
Basswood							9	16	23	21		
Sugar Maple										15	36	
Basswood										13		
Basswood										18		
Totals in Numbers Present	1	1	2	4	12	15	15	15	15	18	12	8

Reproduction under 6″
Number of Seedlings

Species	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940		
Sugar Maple	1	3	3	3	3	3	4	1	2	1		
Basswood	4	5	10	6	2	1	1	1	2			
Black Ash	1		2	1								
Black Cherry			1									
Shagbark Hickory				1								
Bitternut Hickory						1						
Slippery Elm										1		
Totals	6	8	16	11	5	5	5	2	4	2		

The record shows how persistent can be the Crataegus. Three of the four Crataegus have persisted for 20 years compared to only one of the seven elm. The composition of the quadrat shows very little change during the 20-year period. Although red oak is represented in the composition of the quadrat, the growth and development of the seedlings are unsatisfactory. Rodents repeatedly cut back the red oak. The record of the one red oak (1934 to 1950) is representative of the way the species seems to develop under woods conditions. This quadrat record is very much like that secured in many other woods where species like hawthorn and elm do survive when woods are grazed. The severe competition for space that these species give to the newly germinated seedlings of oak, maple and ash makes their establishment less probable.

The quadrat record shown in Table III is similar to the others except that only one seedling was tagged in 1931 and neither Crataegus nor elm were present. Basswood is the dominant species in this quadrat. During the 20-year period more basswood seedlings started growth and more of them survived and were present in 1950, than any other species. The record of seedlings under 6 inches in total height gives a total of 32 basswood and 24 sugar maple. Only one sugar maple seedling was tagged and this one was present for only 5 years (1940-1945). Apparently the basswood seedlings recorded in 1933, 1934 and 1935 were later tagged as established seedlings. The record of the seeding in and establishment of basswood is typical of its growth in many woods. It appears to be an invader of dense sod cover and of other ground cover of less density.

The black ash seedling present in 1931 had a very interesting height growth record. Such a height growth record is characteristic of black ash when it is competing with other hardwoods. The one seedling that became established in 1935 shows better height growth and appears to be growing well in competition with basswood.

Summary

The examples shown in the tables could be multiplied many times. They would show variations in the regeneration patterns as they occur from place to place in the natural woods. However, these quadrat records do show that natural regeneration is a slow process and that during the early period of growth, many seedlings make very little height growth. Seedlings also appear to be very tolerant of shade and competition. It is also apparent that reproduction takes place periodically and that environmental factors work to favor one species and not another. In some places a species seems to take over the area while in other places the same species may become temporarily established and then lose out in competition with others.

It is also apparent that the early invaders of the protected woods are not necessarily those that will constitute the overhead stand of the future. A mere tally of seedlings at any one time may be misleading because a large number of trees during the early stages of growth

is not an assurance that the composition of a well stocked stand of young trees will be like that of the seedling or sapling stage. The character of the reproduction below 6 inches in height often varies considerably from year to year. The species predominantly in evidence one year may have almost disappeared and an entire new crop of seedlings, sometimes of a different species, may occupy this height class the following season. Some species are only temporarily in abundance.

Seed production, dissemination, establishment and growth of tree seedlings in the protected woods are cyclic. Certainly the whole process is influenced by local conditions of site. Each quadrat studied shows a distinct pattern of growth and development. One can read into the quadrat regeneration records a partial explanation of the way our hardwood species occur in the woods, as single trees or in groups and having survived the years of competition for a place in the woods, eventually the mixed hardwood stand is established.

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Notes on the Distribution of the Leguminosae in Indiana

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Introduction

In Indiana the Leguminosae represent between four and five percent of the total number of native and naturalized vascular plants. This family with its thirty-two genera and eighty-odd species is fourth in size in the state, being surpassed in the number of species only by the Compositae, Cyperaceae and Gramineae. Here, as elsewhere, the leguminous plants are a conspicuous and often striking element of the vascular flora, and include some of our best known trees, shrubs, and herbs.

The purposes of this paper are (1) to point out the principal patterns of geographical distribution of eighty-seven species of Leguminosae growing spontaneously in Indiana; and (2) to briefly analyze the affinities of the leguminous flora of this state with that of adjacent floristic areas or of other parts of the world.

Data on the distribution in Indiana of the plants discussed herein is based on the treatment of the Leguminosae by Deam (2), and on additional facts contained in the Indiana Plant Distribution Records (3). Works by Braun (1), Fassett (4), Fernald (5), Fox (6), Gambill (7), Jones (8), and Schaffner (9) have been used as sources of reference on distribution of the leguminous species under consideration outside of Indiana. Nomenclature is in most instances that adopted by Deam. When other binomials are considered to be the valid ones, names used by Deam follow in parentheses.

Geographical Distribution and Floristic Affinities

From the standpoint of their patterns of geographical distribution within the state, the Leguminosae fall into roughly six main groups: (1) Species which range generally throughout the state; (2) species found in northern and southern Indiana, but conspicuously lacking in the central part of the state; (3) species occurring only in the northern counties; (4) species found chiefly in both western and northern Indiana; (5) species distributed over the southern third of the state; and (6) species restricted to the extreme southern counties of the state.

A multiplicity of interacting climatic, physiographic and biotic factors express themselves in the creation of many kinds of habitats in the state. The greatly varying combinations of growing conditions provided by these habitats have made it possible for leguminous plants with considerably diversified floristic affinities to become established in Indiana. Therefore, any study of the patterns of geographic distribution of this group of plants leads naturally to a consideration of the floristic affinities of the species comprising the group.

An attempt is made here to indicate the floristic relationships of the species of Leguminosae by grouping them according to the geographical areas in which they are most abundant, or of which they are most characteristic. The following floristic areas are recognized in this study as being represented in the leguminous flora of Indiana. The letters designating each area later in the paper are indicated in parentheses: (1) southeastern woodland plants (SEW), occurring in the wooded areas of eastern and southeastern United States; (2) coastal plain plants (CP), occurring most abundantly in the coastal plain areas of the south Atlantic and Gulf states and the valleys of the Mississippi River and its tributaries; (3) northern plants (N), found most abundantly in northern United States and Canada; (4) prairie plants (P), occurring most commonly in the prairie areas of Illinois, Wisconsin, Minnesota, the Dakotas, Nebraska, Kansas, Iowa, Missouri, Arkansas, Oklahoma and Texas; (5) plants introduced from Eurasia (EUR); (6) plants introduced from the American tropics (TR); and (7) endemic plants (END), or those originally described from Indiana and distributed chiefly within the boundaries of the state.

In the following sections of this paper are listed the plants characterized by the geographical patterns of distribution described above, with the indication of the principal floristic affinity of each.

Species Distributed Generally throughout the State

Cercis canadensis L.—SEW
Cassia fasciculata Michx.—SEW, P
Cassia hebecarpa Fern.—SEW
Gleditsia triacanthos L.—SEW
Gymnocladus dioica (L.) K. Koch.—SEW
Baptisia leucantha T. & G.—P
Medicago sativa L.—EUR
Medicago lupulina L.—EUR
Melilotus alba Desr.—EUR
Melitotus officinalis (L.) Lam.—EUR
Trifolium pratense L.—EUR
Trifolium repens L.—EUR
Trifolium hybridum L.—EUR
Trifolium procumbens L.—EUR
Trifolium agrarium L.—EUR
Psoralea onobrychis Nutt.—P
Tephrosia virginiana (L.) Pers.—SEW
Robinia pseudoacacia L.—SEW
Desmodium nudiflorum (L.) DC.—SEW
Desmodium glutinosum (Muhl.) Wood—SEW
[*D. acuminatum* (Michx.) DC.]
Desmodium canescens (L.) DC.—SEW
Desmodium cuspidatum (Muhl.) Loud.—SEW
[*D. bracteosum* (Michx.) DC.]
Desmodium canadense (L.) DC.—SEW, P

Desmodium paniculatum (L.) DC.—SEW
Desmodium dillenii Darl.—SEW
Vicia villosa Roth—EUR
Vicia caroliniana Walt.—SEW
Amphicarpa bracteata (L.) Fern.—SEW
Apios americana Medic.—SEW
Strophostyles helvola (L.) Britt.—CP

In this group have been included those plants which range from the northern to the southern boundaries, and from east to west within the state. These species are not always found in every county, although some of them are, and are not necessarily abundant in numbers. In fact, some of them are found quite infrequently. Most of these are species which can adapt themselves to a fairly wide range of growing conditions. It will be noted that the majority of these are plants characteristic of the eastern and southeastern woodlands. In Indiana many of these are approaching the northern and western limits of their distribution in the United States. Ten of these are naturalized species, originally introduced from Eurasia. For the most part they are very abundant and widespread, behaving as weeds.

Species Occurring in both Northern and Southern Indiana

Cassia nictitans L.—SEW
Trifolium arvense L.—EUR
Psoralea psoralioides var. *eglandulosa* (Ell.) F. L. Freeman—SEW
Astragalus canadensis L.—P, N, SEW
Desmodium rotundifolium DC.—SEW
Desmodium marilandicum (L.) DC.—SEW
Desmodium ciliare (Muhl.) DC.—SEW
Desmodium rigidum (Ell.) DC.—SEW
Lathyrus palustris var. *myrtifolius* (Muhl.) Gray—N

This group includes those species which may be found in both the lake area of northern Indiana and the unglaciated and hilly regions of the southern part of the state. They are conspicuously rare or absent in the fertile soil of the prairie and till plain areas in central Indiana. *L. palustris* var. *myrtifolius* is a more northern plant which is close to its southerly limit in southern Indiana. The species indicated by SEW are at the northern limit of their distribution in northern Indiana.

Species Occurring only in Northern Indiana

Baptisia tinctoria var. *crebra* Fern.—SEW
Lupinus perennis L.—SEW, N
Trifolium dubium Sibth.—EUR
Vicia americana Muhl.—N
Lathyrus ochroleucus Hook.—N
Lathyrus maritimus (L.) Bigel.—N
[*L. japonicus* var. *glaber* Fern.]

Lathyrus venosus var. *intonsus* Butters & St. John—N
Lathyrus palustris var. *linearifolius* Ser.—N

Of the two species listed as southeastern plants in this group, *Baptisia tinctoria* var. *crebra* is near the northern limit of its distribution; the range of *Lupinus perennis* extends farther north from Indiana into Wisconsin and Minnesota, as well as into northern New England. The latter species has, therefore, a distribution which would make possible the inclusion of it as a northern plant. With the exception of *Trifolium dubium,* introduced from Eurasia and having a very limited distribution in Indiana, the others of this group of plants are distinctly northern and western in their distribution. *Vicia americana* occurs not only in the northern states and southern Canada, but is widely distributed through the western and southwestern states. The latter species and *Lathyrus ochroleucus, L. maritimus,* and *L. palustris* var. *linearifolius* are wide-ranging, extending from the Atlantic to the Pacific coasts in the northern United States and Canada.

Species Occurring in Northern and Western Indiana

Baptisia leucophaea Nutt.—P
Psoralea tenuiflora Pursh—P
Amorpha canescens Nutt.—P.
Dalea alopecuroides Willd.—P
Petalostemum purpureum (Vent.) Rydb.—P
Petalostemum candidum (Willd.) Michx.—P
Desmodium sessilifolium (Torr.) T. & G.—SEW, P
Desmodium illinoense Gray—P
Lespedeza capitata Michx.—P, SEW

All members of this group can be considered as prairie species, and they occur in the parts of Indiana where there are prairie habitats. With the exception of *Desmodium sessilifolium* and *Lespedeza capitata* they are all more abundant to the west and south of Indiana than they are east of it. *Petalostemum purpureum, P. candidum,* and *Desmodium illinoense* reach the eastern limit of their distribution in Indiana.

Species Occurring in the Southern Third of Indiana

Desmanthus illinoensis (Michx.) MacM.—P
Cassia marilandica L.—SEW
Cladrastis lutea (Michx. f.) Koch—SEW
Desmodium pauciflorum (Nutt.) DC.—SEW
Desmodium laevigatum (Nutt.) DC.—SEW
Desmodium viridiflorum (L.) Beck—SEW
Lespedeza striata (Thunb.) H. & A.—EUR
Lespedeza stipulacea Maxim.—EUR
Lespedeza nuttallii Darl.—SEW
Lespedeza repens (L.) Bart.—SEW
Lespedeza procumbens Michx.—SEW

Strophostyles leiosperma (T. & G.) Piper—CP
Strophostyles umbellata (Muhl.) Britt.—CP

Lespedeza striata and *L. stipulacea* have been introduced from eastern Asia as forage crops and have escaped throughout the southeastern states. *Desmanthus illinoensis*, a prairie plant which may have been introduced into Indiana from the west, approaches the northeastern limit of its distribution in this state. The remaining plants of this group, with the exception of *Strophostyles leiosperma* which follows the Mississippi Valley into Wisconsin, reach the northern limit of their distribution in Indiana.

Species Restricted to Extreme Southern Indiana

Cassia occidentalis L.—TR
Gleditsia aquatica Marsh.—CP
X *Gleditsia texana* Sarg.—CP
Baptisia australis (L.) R. Br.—SEW
Crotalaria sagittalis L.—SEW, CP
Trifolium reflexum var. *glabum* Lojacono—SEW, P
Psoralea stipulata T. & G.—END
Amorpha fruticosa L.—SEW, CP
Wisteria macrostachya Nutt.—CP
Stylosanthes biflora (L.) BSP.—SEW, CP
Lespedeza stuevei Nutt.—SEW
Clitoria mariana L.—CP, SEW
Galactia volubilis (L.) Britt.—CP
Phaseolus polystachyus (L.) BSP.—CP

This group consists of species which, for the most part, are more abundant in the warmer portions of south central and southeastern United States. They have advanced northward chiefly along the eastern coastal plain and in rich river valleys in the interior. Only the southern counties of Indiana afford the climatic and physiographic conditions required by these species. *Trifolium reflexum* var. *glabrum*, the single native *Trifolium* in this state, offers the only exception in this group to the above statements. This variety seems to be the western form of the species, and is quite at home in prairie habitats in Illinois, Iowa, South Dakota, and south to Oklahoma.

Those species indicated by the letters CP have almost certainly migrated into Indiana along the Mississippi, Ohio, and Wabash Rivers. The type specimen of *Psoralea stipulata* comes from Clark County, Indiana (collected in 1839). The validity of this species is questionable, and the plant now seems to be extinct. *P. stipulata* appears to be the only truly endemic leguminous species reported from Indiana. *Cassia occidentalis*, reported only from Floyd County, occurs most abundantly in the tropics of both the Old and New Worlds.

Summary and Conclusions

1. The following patterns of geographical distribution are exhibited by the Leguminosae in Indiana:
   a. Occurring throughout the state; 34 species.
   b. Occurring in both the northern and southern parts, but absent in the central area; 9 species.
   c. Occurring in the north only; 8 species.
   d. Occurring in both the northern and western parts of the state; 9 species.
   e. Occurring in the southern one-third of the state; 13 species.
   f. Occurring in the extreme south; 14 species.
2. The largest number of leguminous species is found in southern Indiana, the number diminishing progressively northward.
3. On the basis of their floristic affinities the leguminous plants of Indiana can be divided into the following categories:
   a. Southeastern and eastern woodland plants; 44 species, comprising 50.5% of the leguminous flora.
   b. Coastal plain and Mississippi Valley plants; 10 species, comprising 11.5%.
   c. Northern plants; 6 species, comprising 6.8%.
   d. Prairie plants; 12 species, comprising 13.7%.
   e. Plants naturalized from Europe, Asia, or tropical America; 15 species, comprising 17.1%.
   f. Endemic plants; 1 species, comprising 1.1% of the leguminous flora of the state.
4. The most widespread species in the state are certain of the southeastern woodland plants and naturalized weed-like species from Eurasia.
5. A majority of the species limited to northern Indiana are of northern floristic affinity and are close to the southern limit of their distribution in the United States.
6. Most of the species limited in distribution to both northern and western Indiana are prairie species which are, for the most part, more abundant west and south of Indiana than they are east of it.
7. Species occurring throughout the southern third of Indiana are southeastern woodland or coastal plain plants which are near the northern limit of their U. S. distribution in Indiana.
8. The majority of species restricted to extreme southern Indiana are plants of the coastal plain and lower Mississippi Valley which are also near the northern limit of their distribution in the United States.
9. The state of Indiana is so located geographically that species from several floristic areas converge within its boundaries, a

condition which is partly responsible for the surprising richness of its vascular flora.

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The Activity of Thiolutin Against Certain Fungi and Seed-borne Diseases[1]

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Interest in anti-fungal antibiotics has its origin in a number of rather diverse possibilities of application, in addition to purely scientific interest in antagonism as such. The first of these, which has received perhaps the major share of attention up to the present time is the possibility of the development of an antibiotic to combat certain fungi which cause human disease and are resistant or slow to respond to present methods of treatment. Then there is a group of plant pathogens which might be controlled practicably by an antibiotic, assuming that it could be produced at a reasonable cost. Finally there is the possibility that the study of the chemical structure of anti-fungals might lead to valuable synthetic fungicides.

Several antibiotics of antifungal activity have been isolated from strains of *Streptomyces albus*. Jump (2) reported the antifungal activity of strain, the active principle of which is thermostable and very low in phytotoxicity, but which has proved difficult to isolate. Other antibiotics from strains of this same species include Endomycin, isolated by Gottlieb and coworkers (1) and Thiolutin which was isolated by Tanner and associates, and with which this report is chiefly concerned.

The effect of Thiolutin on 9 phytopathogenic fungi was studied *in vitro*. The test organisms were grown in petri plates on potato dextrose agar with various amounts of Thiolutin incorporated. The concentrations of the antibiotic ranged from 0.1 ppm. to 100 ppm. depending upon the resistance of the fungus being tested. Four replicates were run at each concentration, and controls were grown on the same type of agar without Thiolutin. The amount of growth of the colony in each plate was expressed as the average of four measurements of the diameter of the colony, and the data of the four replications were, in turn, averaged. Data were recorded at 24 hour intervals for 8 to 11 days, depending upon the rapidity of growth of the fungus. The experiment was not terminated until the diameter of the control colony was at least 9 cm., which was the diameter of the petri plate.

It was difficult to obtain complete solution of the antibiotic in water at the higher concentrations, so the antibiotic was first dissolved in a small quantity of acetone, and water was added to give the required dilution. In such cases acetone was also added in equal amount to the control. The amount of acetone did not exceed 5% in any case, which had been found by previous experiment to produce no significant difference in the rate of growth of the fungus.

[1] Samples of Thiolutin and Actidione were supplied by Charles Pfizer & Co. and the Upjohn Co. respectively. The authors also wish to express thanks to Dr. M. D. Whitehead of Texas Agricultural and Mechanical College and Dr. A. L. Smith of Alabama Polytechnic Institute for supplies of diseased oat and cotton seed.

The fungi used in these experiments, and the plant diseases of which they are causal agents were: *Alternaria solani* (early blight of potato), *Colletotrichum gossypii* (cotton anthracnose), *Fusarium lycopersici* (tomato wilt), *Helminthosporium sativum* (dry-land foot rot of wheat), *Pythium debaryanum* (damping off), *Phomopsis citri* (citrus stem end rot), *Rhizoctonia solani* (damping off), *Sclerotinia fructicola* (brown rot) and *Sphaeropsis ulmicola* (elm canker). These were grown for inoculum in petri plates for 24-72 hours depending upon the speed of growth. Small disks of agar bearing the fungus mycelium were then cut from the edge of the colony and transferred to the plates containing the antibiotic and to the controls.

All of the fungi tested were inhibited by the antibiotic, but the response and the concentration required for inhibition varied with the fungus. On the basis of these variations the fungi tested could be

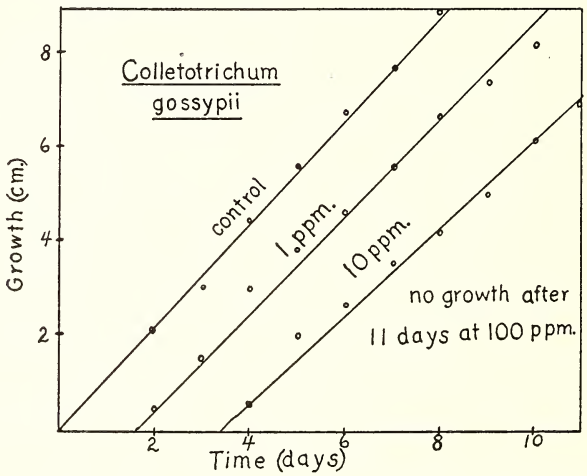

Fig. 1. Growth of *Colletotrichum gossyppii* at various concentrations of thiolutin.

divided into three categories. The highly sensitive ones were inhibited completely by concentrations of 10 ppm or less and included Pythium, Sphaeropsis, and Sclerotinia. Those in the second category of intermediate sensitivity were completely inhibited between 50 and 100 ppm. and included Colletotrichum, Phomopsis and Rhizoctonia. The third category of comparatively resistant fungi showed growth even at 100 ppm. although it was delayed until at least the 7th day. This group included Alternaria, Fusarium and Helminthosporium.

The initiation of growth was usually progressively delayed as the concentration of Thiolutin in the medium increased. There was also some variation in the rate of growth among the different fungi. In a graph such as that showing the growth of Colletotrichum (Fig. 1) the slopes of all of the curves are approximately equally steep, indicating that the rate of growth was not retarded by the antibiotic after the

organism had overcome the original inhibition. In other instances, as is seen in the graphs of Pythium and Alternaria there is a progressive flattening of the growth curves with increasing dosage, showing a continuing inhibitory effect which varies directly as the concentration of the antibiotic increases. (Fig. 2, Fig. 3).

When the fungi growing on the higher concentrations of the antibiotic medium were transferred to antibiotic-free medium they grew normally and required the original inhibitory concentration to suppress growth. Their rate of growth, even after several such transfers, was unchanged from that of the original controls. Thus there was evidence neither of increasing resistance nor increasing sensitivity. Since the antibiotic is fungistatic at these levels, the growth of some of the

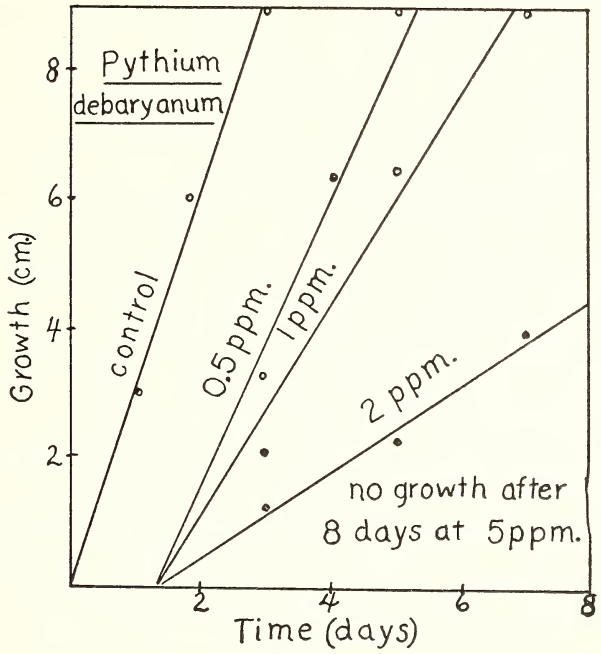

Fig. 2. Growth of *Pythium debaryanum* at various concentrations of thiolutin.

fungi after an initial delay might indicate a gradual reduction in the activity of the antibiotic following incorporation in the medium.

Before attempting to use Thiolutin as a seed protectant, some information was obtained with respect to its phytotoxicity. Young tomato plants were sprayed at the six leaf stage with suspensions and solutions of Thiolutin at concentrations of 6.5, 12, 25, 50, 100 and 200 ppm. No foliar injury was noted, even at the highest concentration. Comparative tests with Actidione, an antifungal antibiotic from *Streptomyces griseus*, indicated that Thiolutin was superior in this respect as

Actidione showed definite phytotoxic symptoms at the higher levels of concentration.

Root systems of young plants of corn, peas, tomatoes, and sunflowers were immersed for a week in nutrient solutions to which had been added 1, 10, 50 and 100 ppm. of Thiolutin and no injury to the root system was noticed except for some evidence of stunting at 100

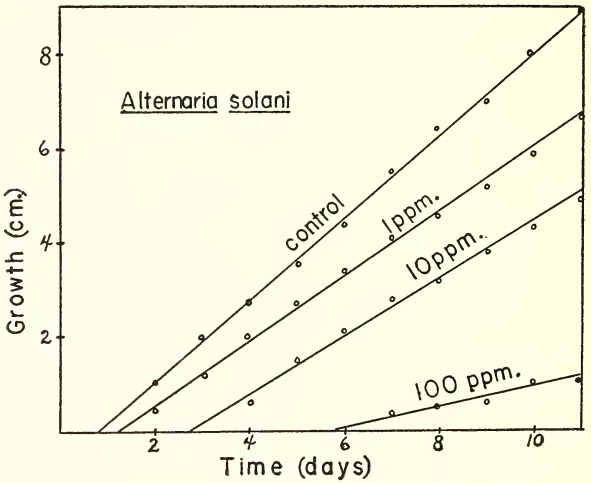

Fig. 3. Growth of *Alternaria solani* at various concentrations of thiolutin.

ppm. A comparative set of experiments with Actidione showed greater phytotoxicity than was encountered with Thiolutin.

The phytotoxic effects of Thiolutin and Actidione on seed germination were evaluated by soaking seeds of corn, peas and radish for 8 hours prior to sowing in solutions of the antibiotics at various concentrations. One hundred seeds were tested of each variety at each concentration, and concentrations of 1, 10, 50 and 100 ppm. were used. Following treatment in the solution, the seeds were rinsed thoroughly in running water and placed to germinate in petri plates between layers of moist filter paper. The results of this experiment are summarized in Table I. Thiolutin does not appear to inhibit germination of the

TABLE I. The Effect of Thiolutin and Actidione upon Seed Germination.

SEED	% GERMINATION								
	Control	Thiolutin (ppm.)				Actidione (ppm.)			
		1	10	50	100	1	10	50	100
Corn	95	95	96	95	95	42	39	21	9
Peas	100	100	100	100	100	33	31	9	0
Radish	100	100	100	98	100	46	12	0	0

seeds tested at any of the levels employed. Actidione, however, is definitely inhibitory. The inhibition by Actidione increases directly as the concentration and appears to effect radish the mostly strongly and corn the least.

The low phytotoxicity of Thiolutin made it appear practicable to test it as a seed protectant. Both dusting and soaking treatments were employed with oat seeds infected with *Helminthosporium* and cotton seeds infected with *Colletotrichum gossypii*. The same technique was used in the soaking treatments that was previously mentioned in the germination experiments, except for changes in the concentration. In the case of dust treatments the antibiotic was placed with the seeds in bottles which were then stoppered and rolled mechanically for 45 minutes to insure uniform coverage. Spergon and New Improved Ceresan were used in other treatments as a basis for evaluation of results, and were applied at concentrations recommended by the manufacturers. The concentrations of Thiolutin ranged from 1/16% to 2% of the seed weight. Following treatment the seeds were planted, and data on germination and disease incidence were recorded. It appears from the results with oats (Table II) that a 1% Thiolutin dust was the most effective treatment, although the soaking treatments even at the lowest concentration were superior to Spergon. In the case of the cotton

TABLE II. Thiolutin as a Seed Treatment for Oats infected with Helminthosporium.

TREATMENT	% GERMINATION	% DISEASE
Control	88	53
1% Thiolutin (soaking)	85	6
1/2% Thiolutin (soaking)	90	14
1/4% Thiolutin (soaking)	90	14
1/8% Thiolutin (soaking)	83	17
1/16% Thiolutin (soaking)	83	24
1% Thiolutin (dusting)	96	3
Spergon (dusting)	95	32

TABLE III. Thiolutin as a Seed Treatment for Cotton Infected with Anthracnose.

TREATMENT	% GERMINATION	% DISEASE
2% Thiolutin (dusting)	80	32
1% Thiolutin (dusting)	80	42
1/2% Thiolutin (dusting)	78	46
Spergon	72	30
New Improved Ceresan	80	6
Control	80	65

seed, although Thiolutin treatments reduce disease in comparison to untreated controls, they do not afford as much protection as Spergon or New Improved Ceresan. The cotton seeds were not delinted and it is possible that improved results might have been obtained by such a procedure, since the effect of the relative volatility of the fungicides would then be less significant. Since Thiolutin was not available at the time in large quantities it was necessary to limit the variety of the treatments.

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Notes on Indiana Liverworts—IV. A Report of Recent Collections[1]

Kenneth A. Wagner, Florida State University

Two collecting trips into Indiana, one in August 1950, the other in September, 1951, have resulted in the discovery of new stations for several species. Among these species are *Frullania asagrayana* and *Plectocolea crenulata*, which are new state records. The latter had been reported for Indiana (Underwood, 3) but that report, as the present writer has shown (Wagner, 5) was based on *P. crenuliformis*, which, as the name might suggest, much resembles *P. crenulata*.

The 1950 trip, although it covered several counties, was significant only at one station, a small creek that crossed U. S. 460 about 24 miles east of Mariah Hill. Sandstone outcropping at this station produces a habitat similar to that of Fern in Putnam county and Turkey Run in Parke county. The majority of species found at this site are relatively rare or at least uncommon as compared with those found on limestone or clay areas. Of the ten species reported here from Crawford county, three, if we include *Fossombronia foveolata*, are known only from that county; two from one other county; and three from two other counties in Indiana. The average number of Indiana counties recorded for the limestone, soil and bark species reported here is twenty-four.

A discussion of the synonomy of *Porella platyphylla* (L.) Lindb. (Wagner, 6) states that the reduction of *P. platyphylloidea* to synonomy would necessitate adding seven counties to the list of those from which *P. platyphylla* is known. At the time this paper (Wagner, 6) was sent to the editors, the writer was not aware that a paper submitted the previous year was not to be published. Because of this, three of the seven county records, Brown, Jay and Union, did not appear until the following year (Wagner, 7).

The collection of *Fossombronia foveolata* reported here from Crawford county is the first Indiana specimen seen by the writer. Ammons (1) lists Indiana in the range of *F. foveolata* but does not indicate the source of the record. Frye and Clark (2), however, do not include Indiana. Underwood (4), shortly after leaving DePauw University, published his studies on the entire genus as it was known in North America at that time. According to Underwood, *F. foveolata* had been found in British Columbia, Ontario, Maine, New Jersey and Delaware. Since then it has been found in most of the New England states, in Michigan and Wisconsin, and throughout the southern United States.

The following citations list only new county and state records. One set of specimens is kept in the writer's collection; a duplicate set may be found in the herbarium of DePauw University, Greencastle, Indiana.

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[1] Contribution No. 48, Botanical Laboratory, Florida State University.

All of the collections listed for Crawford county were made on sandstone or thin soil over sandstone along a small stream which crossed U. S. 460 at a point about 24 miles east of Mariah Hill.

Anthoceros laevis L. Madison Co.: on soil, Mounds State Park, Sept. 4, 1951, Wagner 2501. This is the farthest eastward the species has been found in Indiana.

Calypogeia sullivantii Aust. Crawford Co.: Aug. 28, 1950, Wagner 2502, 2533. Previously known in Indiana only from LaPorte county which borders on Lake Michigan. Its discovery in Crawford county, which lies along the Ohio River, is a considerable intra-state range extension. *Calypogeia trichonmanis* (L.) Corda, considerably more frequent in Indiana and known from Crawford county, was not found in any of the collections made in August, 1950.

Cephalozia bicuspidata (L.) Dum. Crawford Co.: Aug. 28, 1950, Wagner 2503. Previously known in Indiana only from Parke and Ripley counties.

C. connivens (Dicks.) Lindb. Crawford Co.: Aug. 28, 1950, Wagner 2533.

Cephaloziella elaschista (Jack) Shiffn. Madison Co.: Mounds State Park, on rotten wood, Sept. 4, 1951, Wagner 2504. Formerly known in Indiana only from LaPorte county.

C. hampeana (Nees) Schiffn. Crawford Co.: Aug. 28, 1950, Wagner 2538 in part.

Fossombronia foveolata Lindb. Crawford Co.: Aug. 28, 1950, Wagner 2507 in part.

Frullania asagrayana Mont. Crawford Co.: Aug. 28, 1950, Wagner 2509, 2510. This new state record brings the number of Indiana species in the genus to six. *Frullania* now has more species reported for the state than any other genus of liverworts.

F. eborascensis Gott. Clay Co.: on elm bark, Shakamak State Park, Sept. 6, 1951, Wagner 2511; Green Co.: Shakamak State Park, Sept. 6, 1951, Wagner 2512; Hancock Co.: along route 9, three miles south of Greenfield, Sept. 4, 1951, Wagner 2513; Sullivan Co.: Shakamak State Park, Sept. 6, 1951, Wagner 2515, 2516.

F. squarrosa (R. Bl. & Nees) Dum. Madison Co.: Mounds State Park, Sept. 4, 1951, Wagner 2517.

Leucolejeunea clypeata (Schw.) Evans. Crawford Co.: Aug. 28, 1950, Wagner 2518. Previously reported from two counties.

Lophocolea cuspidata (Nees) Limpr. Madison Co.: on rotten wood, Mounds State Park, Sept. 4, 1951, Wagner 2519, 2520; Sullivan Co.: Shakamak State Park, Aug. 6, 1951, Wagner 2522.

L. heterophylla (Schrad.) Nees. Clay Co.: on bark, Shakamak State Park, Sept. 6, 1951, Wagner 2523; Green Co.: Shakamak State Park, Sept. 6, 1951, Wagner 2526, 2527; Sullivan Co.: Shakamak State Park, Sept. 6, 1951, Wagner 2531.

L. minor Nees. Sullivan Co.: Shakamak State Park, Sept. 6, 1951, Wagner 2532. Not previously collected in Indiana south of Putnam county.

Plectocolea crenulata (Sm.) Evans. Crawford Co.: Aug. 28, 1950, Wagner 2534. The first authentic report for the state.

P. hyalina (Lyell) Mitten. Crawford Co.: Aug. 28, 1950, Wagner 2536.

Porella platyphylla (L.) Lindb. Green Co.: Shakamak State Park, Sept. 6, 1951, Wagner 2537.

Radula obconica Sull. Crawford Co.: Aug. 28, 1950, Wagner 2538. Reported also from Parke and Putnam counties.

Reboulia hemisphaerica (L.) Raddi. Madison Co.: Mounds State Park, Sept. 4, 1951, Wagner 2539.

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7. ———————— 1950. Notes on Indiana Liverworts—III. Some new county and state records. Proc. Indiana Acad. Sci. **59**:112-114.

Studies in Indiana Bryophytes IX

WINONA H. WELCH, DePauw University

The introductory remarks for this study are comparable to those of number eight in the series. The writer is indebted to the Indiana Academy of Science and the Graduate Council of DePauw University for research grants and to the University of Iowa for two honoraria. The latter were used during the summers of 1950 and 1951 at the Iowa Lakeside Laboratory, in research on Indiana mosses under the leadership and generous counsel of Dr. H. S. Conard. The author in this way wishes to express deep appreciation to Dr. Conard.

LESKEACEAE

Plants in tufts or mats; stems prostrate, ascending or erect; leaves costate; majority of leaf cells papillose, those of basal portion of leaf slightly papillose to smooth; paraphyllia present in many species.

Subfamily THUIDIEAE

Stems rather stiff, pinnately branched; branches complanate; capsules inclined, unsymmetric; peristome perfect, with well developed cilia.

Key to the genera of Thuidieae

Stem leaves with paraphyllia-like filaments at base; apical cells of branch leaves without papillae ..... *Helodium*

Stem leaves without paraphyllose filaments at base; apical cells of branch leaves with 1-4 papillae ..... *Thuidium*

HELODIUM

Plants forming soft, green, yellowish green, or brownish tufts; stems usually simple, erect or nearly so, pinnately branched; branches slender, attenuate; paraphyllia abundant and matted on stem, filamentous, freely branched; leaves costate, concave, plicate, with paraphyllia on base; leaf cells smooth or unipapillate over the lumen or at the upper angle; capsule inclined to horizontal, more or less arcuate, somewhat cylindrical; peristome double, with 3 cilia, endostome with high basal membrane, carinate; operculum conic.

Key to species of Helodium

Stem irregularly branching; leaf costate nearly to apex; papillae on leaf cells small.

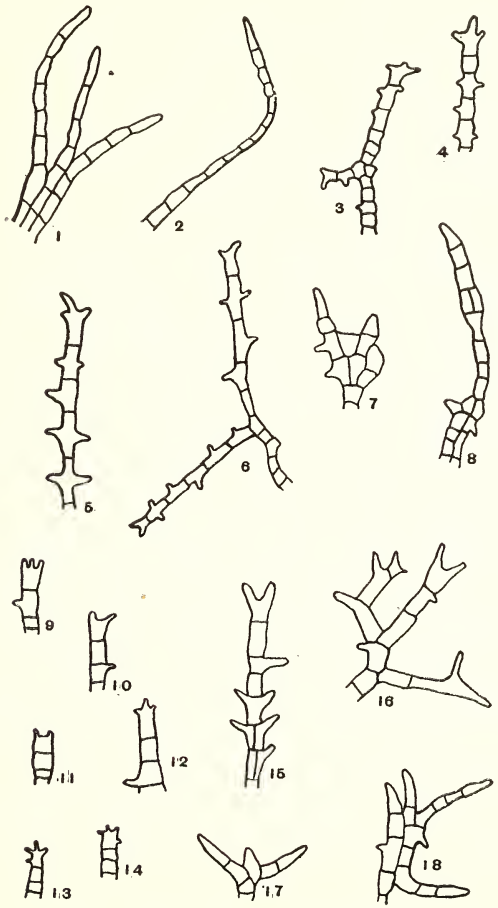
Median leaf cells short linear-oblong to linear-rhomboid, usually smooth, sometimes papillose at distal end ..... *H. paludosum*

Median leaf cells elliptic to oval, frequently subcentrally papillose ..... *H. paludosum* var. *Helodioides*

Stem very regularly pinnately branching; leaf costate to middle or slightly above; large papillae at distal angle of leaf cells .... *H. Blandowii*[1]

H. paludosum (Sull.) Aust. (Figs. 1, 2, 19.) Allen, Jefferson, and Porter counties.

H. paludosum var. *Helodioides* (R. & C.) Grout. Allen and Lagrange counties.



Figs. 1-30, enlarged, unless otherwise indicated. Figs. 1-18, original; 19, 23, 24, 29, 30, Grout, Mosses with Hand-lens and Microscope, by permission; 20-22, 25-28, Conard, How to know the Mosses, by permission. Figs. 1-18, paraphyllia. Figs. 1-2. *Helodium paludosum.* Figs. 3-4. *Thuidium abietinum.* Figs. 5-6. *T. delicatulum.* Figs. 7-8. *T. microphyllum.* Figs. 9-12. T. *minutulum.* Figs. 13-14. *T. pygmaeum.* Figs. 15-16. *T. recognitum.* Figs. 17-18. *T. virginianum.*

[1] *Helodium Blandowii* (W. & M.) Warnst. not yet reported from Indiana.

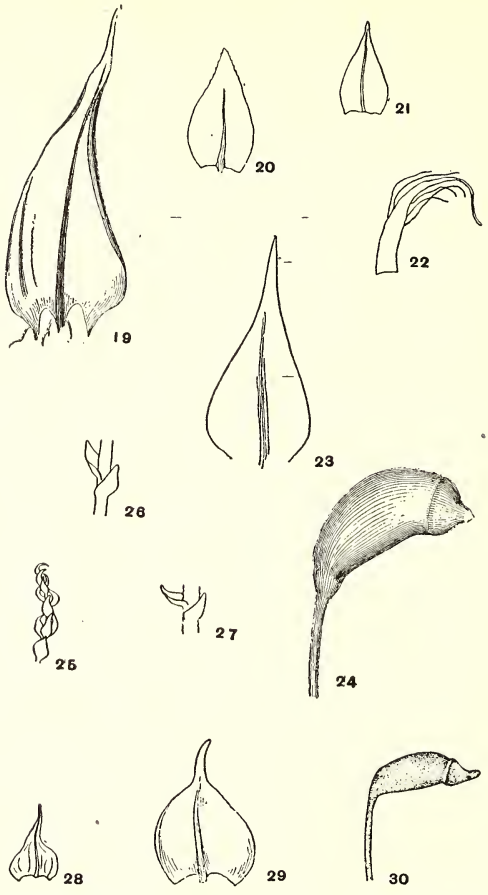


Fig. 19. *Helodium paludosum* (Grout, pl. 53), stem leaf. Fig. 20. *Thuidium abietinum* (Conard, fig. 133), stem leaf. Figs. 21-22. *T. delicatulum* (Conard, fig. 134). Fig. 21. Stem leaf. Fig. 22. Perichaetial leaf. Figs. 23-24. *T. microphyllum.* Fig. 23. Stem leaf, X 60 (Grout, fig. 130). Fig. 24. Capsule (Grout, pl. 55). Figs. 25-26. *T. minutulum* (Conard, fig. 132). Fig. 25. Dry, foliated branch. Fig. 26. Smooth branch. Fig. 27. *T pygmaeum* (Conard, fig. 132), papillose branch. Fig. 28. *T. recognitum* (Conard, fig. 134), stem leaf. Figs. 29-30. *T. virginianum* (Grout, pl. 54). Fig. 29. Stem leaf. Fig. 30. Capsule.

THUIDIUM (FERN MOSSES)

Plants usually stiff, in yellowish, greenish or brownish mats or cushions; stems prostrate to erect, pinnately branched, often regularly and in one plane, resembling the frond of a fern; branches simple to bipinnate; paraphyllia more or less abundant on stems and branches; cauline leaves plicate, costate, papillose on one or both surfaces; inner perichaetial leaves generally lanceolate, often with an acuminate to

filiform apex, sometimes margins ciliate; seta long; capsules more or less arcuate, somewhat cylindrical; peristome double, with cilia, endostomal band approximately 1/3 the length of the teeth; operculum conical to rostrate.

Key to species of Thuidium

1. Paraphyllia on stems simple or branched, sometimes 2, 3, or more cells wide, linear to multiform, cells numerous ..... 2.
   2. Apical cell of paraphyllia with 2-4 papillae ..... 3.
      3. Stems closely once pinnate; branches slender, attenuate, cylindrical or terete when dry ..... *T. abietinum*
      3. Stems loosely pinnate; branches pinnate to bipinnate ..... 4.
         4. Paraphyllia with lateral papillae usually only at ends of cells; margins of perichaetial leaves not ciliate ..... *T. recognitum*
         4. Paraphyllia with lateral papillae usually only at center of cells or approximately so; margins of inner perichaetial leaves ciliate ..... *T. delicatulum*
   2. Apical cell of paraphyllia with a single terminal pappila ..... 3.
      3. Cauline leaves rounded ovate, 0.6-0.8 mm. long, abruptly short acuminate; operculum short rostrate, obtuse, approximately 1/3 the length of the urn ..... *T. virginianum*
      3. Cauline leaves broadly ovate to ovate-lanceolate, narrowly acuminate ..... 4.
         4. Cauline leaves 0.75-1.20 mm. long, gradually long and narrowly acuminate; operculum short conical, apiculate or obtuse, or mammillate ..... *T. microphyllum*
         4. Cauline leaves 1.30 mm. or more in length, abruptly narrowed to long narrow acumination ..... *T. microphyllum* var. *lignicolum*

1. Paraphyllia on stems not branched, linear, 2-6 cells long ..... 2.
   2. Branches of stem smooth; paraphyllia 3-6 cells long; on bark, usually ..... *T. minutulum*
   2. Branches of stem papillose; paraphyllia 2-5 cells long; on rocks, usually ..... *T. pygmaeum*

T. abietinum (Brid.) Bry. Eur. (Figs. 3, 4, 20.) Lake county.

T. delicatulum (Hedw.) Mitt. (Figs. 5, 6, 21, 22.) Allen, Blackford, Clark, Crawford, Delaware, Dubois, Fountain, Hamilton, Harrison, Henry, Jasper, Jay, Jefferson, Lagrange, Lake, Laporte, Lawrence, Madison, Marshall, Martin, Monroe, Montgomery, Owen, Parke, Perry, Pike, Porter, Putnam, Saint Joseph, Steuben, Warren, Wayne, and Wells counties.

T. microphyllum (Hedw.) Best. (Figs. 7, 8, 23, 24.) Clark, Gibson, Grant, Knox, Lake, Laporte, Montgomery, Perry, Putnam, Starke, Steuben, and Warrick counties.

T. microphyllum var. *lignicolum* (Kindb.) Best. Putnam county.

T. minutulum (Hedw.) Bry. Eur. (Figs. 9-12, 25, 26.) Dubois, Jefferson, Laporte, Montgomery, Putnam, and Wayne counties.

T. pygmaeum Bry. Eur. (Figs. 13, 14, 27.) Jefferson, Martin, Monroe, Montgomery, Parke, and Putnam counties.

T. recognitum (Hedw.) Lindb. (Figs. 15, 16, 28.) Brown, Carroll, Clark, Delaware, Harrison, Jefferson, Lawrence, Madison, Montgomery, Noble, Owen, Parke, Porter, Putnam, Ripley, Steuben, Tippecanoe, Vermillion, Warren, Washington, and Wayne counties.

T. virginianum (Brid.) Lindb. (Figs. 17, 18, 29, 30.) Clark, Dearborn, Fountain, Gibson, Hamilton, Jefferson, Knox, Lake, Lawrence, Marshall, Martin, Monroe, Montgomery, Orange, Parke, Perry, Porter, Posey, Putnam, Ripley, Spencer, Starke, Steuben, Washington, and Wayne counties.

CHEMISTRY[1]

Chairman: R. L. Hicks, Franklin College

E. L. Haenisch, Wabash College, was elected chairman for 1952

ABSTRACTS

A course in the nature of matter-energy for the first semester of general chemistry. George A. Scherer, Earlham College.—The objective of the course is to present the broad concepts of the present-day views of the nature of matter-energy. It should be followed by a descriptive course about the properties, preparation and uses of specific kinds of matter.

The course begins with a consideration of the fundamental particles of matter (electrons, protons, neutrons, etc.), followed by the usual classification of matter and the study of the changes of matter, including the laws of chemical changes.

The presentation of the structure of matter explains the periodic system, valence, radioactivity, nuclear fission, etc. In the same way the gas laws, the kinetic molecular theory and crystal structure grow naturally out of a study of the states of matter.

The dispersed condition of matter includes a treatment of colloids, solutions, electrolytes and Faraday's laws of electrolysis. Acids and bases are presented according to the proton theory. The course closes with a study of equilibrium.

The laboratory work contains many of the usual experiments illustrating the laws, principles and processes mentioned above. New Radioactivity and Periodic System and Atomic Structure.
experiments used are Wave Nature of Electrons, Ionization Potentials,

When is an equation balanced? R. L. Hicks, Franklin College.—

The non-science one-semester course in organic chemistry. E. Campaigne, Indiana University.—In determining the material to be presented in a one-semester course in Organic Chemistry for non-science majors, it is important to have a clear understanding of the specific objectives of the course, and the nature and composition of the student body of the course. Most important in the latter respect is a knowledge of the previous chemical training of the student. In most cases for this type of course the student has had one semester or one year of general chemistry.

The chief purpose of such a course is to impart a cultural knowledge of organic chemistry, so that current newspapers and magazines

[1] Several of the abstracts are from a panel discussion on "What Should Be Included in the Chemistry Curriculum of a Small Liberal Arts College?"

dealing with such topics as petroleum products, synthetic rubber, drugs, synthetic blood plasma, etc., can be read with some understanding. To achieve this objective with a student body having only one semester of general chemistry requires careful elimination of much of the material usually given in the year-course in Organic Chemistry, plus careful choice of illustrative material which will relate the student's everyday experiences to the field.

In the choice of experiments for the laboratory, it is also important to have clearly in mind the purposes of the course. The acquiring of technique and special skills is not important for these students, and therefore experiments requiring isolations of products in high yield and of great purity should be minimized. The laboratory should be used chiefly to acquaint the student with organic materials, and to illustrate the lecture. Therefore many test-tube experiments and demonstrations can be used. This serves to speed up the work, and permit coverage of all of the field in one semester.

The course content and the pros and cons of teaching aliphatic and aromatic chemistry together will be discussed.

The second semester of general chemistry for a small liberal arts college. DONALD J. COOK, DePauw University.—The situation usually encountered in the small liberal arts college is one where students who are majoring in other fields besides chemistry are all in the same course. This presents a problem as to what should be presented in such a course so that it will not be too difficult for the non-chemistry major, but still adequate for the chemistry major.

By emphasis on properties of matter as related to inorganic substances, structural inorganic chemistry, complex ions, equilibrium involving common ion effect and Mass Law and by requiring the student to convert what is seen in the laboratory to a logical chemical statement in the form of a balanced equation, the primary goal of giving all students something which is interesting and useful will be accomplished.

So that the lectures and laboratory work can be integrated, it is necessary that the order in which the study of the elements and their compounds is undertaken must follow as closely as possible the ordinary scheme of qualitative analysis as covered in most text-books.

A course in second semester General Chemistry which is conducted with the above motives should, to a great extent, correct the lack of general knowledge of inorganic chemistry which has been evident in chemistry majors from Liberal Arts Schools.

The physical chemistry course in a small liberal arts college. FRANK T. GUCKER, JR., Indiana University.—We may consider three main objectives in a college course in physical chemistry: (1) a description of phenomena and facts, (2) the understanding of experimental methods and their limitations, (3) mathematical correlation of facts and their theoretical interpretation in terms of the laws of thermodynamics and the kinetic theory.

A purely descriptive course with a minimum amount of mathematics is worthwhile for premedical students and those in some of the biological sciences, while a more mathematical course making use of calculus is necessary for students of chemistry, physics, and mathematics. If there are not enough students to warrant both a nonmathematial and a mathematical course in physical chemistry, all of the students can be put into a descriptive course, followed by a one-semester course in elementary thermodynamics, covering the mathematical aspects of physical chemistry.

First-hand information on the reliability of experimental methods is best gained by laboratory work. Much of this can be done with fairly simple equipment, easily within the range of small liberal arts colleges. Students may cooperate on many experiments, and these may be carried out in rotation to reduce duplication of equipment, although the laboratory work cannot then be in step with the lecture material. A group of 26 simple laboratory experiments, mostly taken from the compilation by Professor Ralph L. Seifert, were discussed. These included studies of gases, liquids, solids, thermochemistry, liquid pairs, solutions, chemical kinetics, electrolytes, electrochemistry, surface chemistry, and phase rule.

The content of the qualitative analysis course. NED GUTHRIE, Hanover College.—The content of the course depends upon the background of the student. A more comprehensive course can be presented if the student has a full year of general chemistry in college.

Qualitative analysis is an excellent tool for teaching inorganic chemistry and the applications of elementary principles of physical chemistry to the field of inorganic chemistry. The methods of analysis should be organized around the fundamental laws and theories of chemistry such as the periodic table, law of chemical equilibrium, theory of atomic structure and its applications. The student also has the opportunity to become acquainted with many inorganic substances.

Laboratory work consists of experiments to collect and organize data which is useful in separations and identifications; the analysis of knowns and unknowns.

Most text books are weak on the thought provoking type of questions which helps the students to understand the chemistry involved in the analysis.

Principles of any science have very little meaning to the student until he has had considerable experience in using the laws and theories by applying them to various problems. The course in qualitative analysis is an excellent tool for presenting the fundamental principles of physical inorganic chemistry.

Analytical chemistry—quantitative analysis. EDWARD L. HAENISCH, Wabash College.—The time devoted to quantitative analysis depends on the place occupied by qualitative analysis and instrumental analysis in the chemistry curriculum. For pre-medical students it is also influenced by the content of a possible course in pre-medical physical

chemistry. At Wabash College a sophomore course has been devised wherein everyone takes a common first semester. This consists of qualitative analysis by semi-micro methods for a half term and quantitative analysis, primarily the practice, physico-chemical theory and stoichiometic calculations of neutralization, for the second half. During the second semester everyone takes two lectures in common over a similar treatment of gravimetric analysis (including electrodeposition), volumetric precipitations, redox methods and simple spectrophotometry. The chemistry majors analyze alloys, ores, minerals, etc., during six hours of laboratory weekly. The pre-medical students have a third classroom period to cover additional physico-chemical topics such as gases, solutions and kinetics. In the laboratory these students work three hours weekly and perform simpler analyses than the chemists. In addition they use a pH meter, do electrometric titrations and measure pH colorimetrically. Of eight semester hours in sophomore chemistry the pre-medical students obtains 2 credits in qualitative analysis, 3 in quantitative analysis and 3 in pre-medical physical chemistry. Chemistry majors take an additional senior course in instrumental methods.

The measurement of low pressures at high temperatures. W. H. JOHNSTON and A. W. SEARCY, Purdue University.—The present techniques for the continuous measurement of pressures are extremely difficult to apply at temperatures above 1,000° C. The need for such measurements in vapor pressure studies at very high temperatures has led the authors to design an apparatus for this purpose.

A substance containing a radioactive tracer is vaporized onto a moving tape which passes in front of a shielded Geiger counter. The continuous recording of the output of the counter is calibrated to give the pressure in the vaporization chamber.

Gas phase exchange reactions. W. H. JOHNSTON, Purdue University.—The recent availability of a great variety of stable and radioactive isotopes has made possible the systematic study of exchange reactions in the gas phase. These reactions are discussed in general terms, noting their relationship to ordinary chemical reactions and their importance to chemical kinetics.

A number of specific examples are given with special emphasis on the author's work on the hydrogen chloride-chlorine and the chlorine-chlorine systems.

The reducing action of Grignard reagents on fluorinated carbonyl compounds. E. T. MCBEE and OGDEN R. PIERCE, Purdue University.—The reactions of six Grignard reagents with both trifluoroacetaldehyde and pentafluoropropionaldehyde were studied in order to determine if the amount of fluorine present in the aldehyde affects the degree of reduction and to evaluate the effect of the structure of the alkyl group of the Grignard reagents on the product obtained. In addition, the study was extended to the action of ethylmagnesium iodide on esters of trifluoroacetic, pentafluoropropionic and heptafluorobutyric acids as well as 1,1,1-trifluoroacetone, 3,3-4,4,4-pentafluoro-2-butanone, 3,3,4,4,5,5,5-heptafluoro-2-pentanone, and heptafluorobutyraldehyde.

The products of the reaction of trifluoroacetaldehyde and isopropyl magnesium iodide were trifluoroethanol in 87% yield, and propylene. In the reaction of ethyl magnesium iodide with trifluoroacetaldehyde and pentafluoropropionaldehyde, a very much larger ratio of reduction to addition was obtained with the latter compound. The inductive effect of the fluorinated alkyl groups is believed to account for the abnormally high yield of reduction products produced with Grignard reagents having beta hydrogens. Mechanisms are proposed for the addition and reduction reactions.

The silicides of the transition metals. ALAN W. SEARCY, Purdue University.—Practically all that we know of the chemistry of the metal-silicon compounds was learned fifty years ago by men working with impure materials and without the aid of x-ray diffraction equipment. Because of the great experimental obstacles to the work at that time, some metal silicides were incorrectly identified and many more were overlooked. In the past thirty years many metal silicides have been unambiguously identified by x-ray diffraction analysis, but the properties of these silicides have not been studied. In the present paper the chemical and physical properties of the transition metal silicides are discussed in light of the old chemical information and the recent structural information. The elements that form the most stable silicides are the same as those that form the most stable carbides. The high melting points, the hardness, brittleness, electrical conductivity, and chemical inertness of the silicides are all properties similar to those of the so-called interstitial carbides even though silicon atoms are too large to enter a metal lattice interstitially. Clearly, the influence of the interstitial crystal structures on physical and chemical properties of carbides has been exaggerated.

Mono- and di-valent gaseous compounds of boron and aluminum. ALAN W. SEARCY, Purdue University.—Until recently it appeared that only compounds of boron and aluminum could be prepared in which the metal is tri-valent. In 1940, however, Zintl, Morawietz, and Gastinger[1] reported that when boron and zirconium dioxide were heated together a mono- or di-valent gaseous oxide of boron was evolved. Other workers have since shown that the compounds AlF, AlCl, AlBr, AlI, Al_2O, Al_2S, and Al_2Se exist as gases. None of these compounds has been prepared in the solid state. Methods of studying the gaseous lower halides are discussed, and a brief description is given of unpublished investigations by Daniel Barry and A. W. Searcy which indicate the evolution of a mono- or di-valent chloride of boron when boron trichloride is passed over boron metal. The binding energy in gaseous BCl is discussed.

Organic chemistry—usual one year course. T. C. SCHWAN, Valparaiso University.—There is fairly good agreement on course content, but not on order of presentation of material. Content should include

[1] Zintl, E., W. Morawietz, and E. Gastinger. 1940. Bormonoxide. Zeitschrift fur Anorganisch Chemie. **245**:8-11.

an intensive study of basic organic chemistry emphasizing, in decreasing order of emphasis, nomenclature, properties, reactions, occurrence, preparation, uses and history. The course should begin with a gradual transition from inorganic to organic chemistry beginning organic chemistry proper with the hydrocarbons and continuing with simple derivatives such as halides until the more complex functional groups and combinations have been covered. Aromatic compounds should be presented with alphatic compounds. There should be at least a brief introduction to heterocyclic compounds.

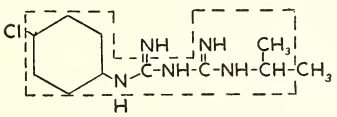
The laboratory work should extend and emphasize a well balanced variety of experiments illustrating techniques, reactions by test tube experiments, preparations taking into account side reactions and purification procedures and a brief introduction to qualitative organic chemistry with unknowns being given for identification throughout the course.

A laboratory text which requires the student to formulate his own laboratory directions might be used as a means of avoiding "cookbook" laboratory procedures.

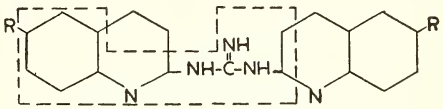
Synthesis of Symmetrical Diquinolylguanidines[1]

G. Bryant Bachman and Martin Hamer, Purdue University

The antimalarial activity of Paludrine (I) and, to a lesser extent, that of certain 2,8′-diquinolylamines (Cooper, 1) has suggested to us the desirability of preparing and testing 1,3-di-(2′-quinolyl)guanidine (II) and its 6,6′-dimethoxy derivative. The structural analogy between these molecules is rather close as may be seen from the following formulas in which similar parts are outlined.



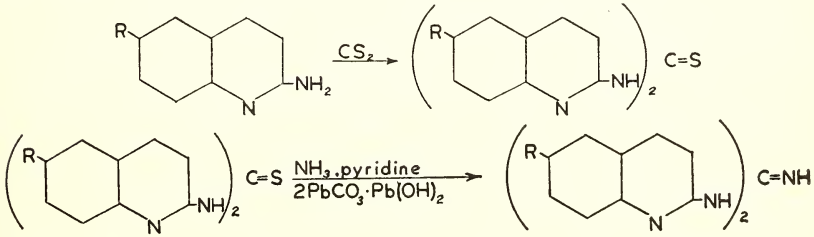
Paludrine I



Diquinolylguanidines
II, R is -H; III, R is -OCH_3

The first attempts to prepare diquinolylguanidine (II) involved reaction between 2-chloroquinoline and guanidine salts. With guanidine carbonate in phenol at 180°, the chief product of the reaction was 2-phenoxyquinoline; however, a small amount (0.2 g.) of a product was obtained which by mixed melting points seemed to be identical with II prepared in a subsequent reaction. With guanidine hydrochloride in moist hexanol, only 2-hydroxyquinoline was obtained. Fusion of 2-chloroquinoline with guanidine carbonate at 210-235° did not alter the chloro compound.

The above unsuccessful attempts to obtain direct arylation of guanidine in satisfactory yields were abandoned in favor of an indirect approach. Topchiev (4) obtained 1,3-di-(2′-pyridyl)guanidine from 2-aminopyridine by condensation with carbon disulfide followed by desulfurization and ammonolysis in the presence of basic lead carbonate. This method was applied successfully by us in the preparation of II and III.



[1] An abstract of a thesis submitted to the faculty of Purdue University by Martin Hamer in partial fulfillment of the requirements for the degree of Master of Science.

Reaction with carbon disulfide was much slower in the quinoline series (3 weeks) than that observed by Topchiev in the pyridine series (4 days). Morover, the yields were less satisfactory (35-37% compared to 65%). Ammonolysis of the thioureas may easily proceed too far (to 2-aminoquinolines) if conditions in the second step of the synthesis are too drastic. Under milder conditions, the yield in this step is good (64%).

Compounds II and III are almost completely insoluble in water, dilute mineral acids and the common organic solvents. This remarkable behavior precludes their testing as antimalarials.

Experimental

Condensation of 2-chloroquinoline with guanidine—(a) In phenol-2-Chloroquinoline, 29.4 g. (0.18 mole), and 8.1 g. (0.09 mole) of guanidine carbonate were heated in phenol, 177.0 g. (1.88 moles), at 180° for 21 hours. The dark reddish-brown mixture was allowed to cool and was then poured into 900 g. of 10% NaOH solution. A dark yellow oil separated which solidified upon cooling. The solid was filtered, washed with aqueous alkali and water, and then recrystallized from ethanol. The first product which separated was recrystallized from pyridine to m.p. 237° (yield 0.2 g.): picrate m.p. 288° d. (uncorr.). These m.p.'s were unchanged when the substances were mixed with authentic samples of 1,3-diquinolylguanidine and its picrate as prepared in later experiments. The second product obtained from the ethanol solution was recrystallized from methanol to m.p. 61.5-62.5°. This compound (10.6 g.) was found to be the known 2-phenoxyquinoline.

Anal. Calcd. for $C_{15}H_{11}ON$: C, 81.42; H, 5.02; N, 6.33. Found: C, 81.50; H, 4.94; N, 6.31.

(b) Without solvent—2-Chloroquinoline, 3.6 g., and guanidine carbonate, 1.0 g., were heated together in a tube to 210° by means of an oil bath. Complete melting did not occur, and upon cooling, most of the chloroquinoline was recovered. Direct fusion at 235° gave similar results.

(c) In hexanol—A mixture of guanidine hydrochloride, 9.6 g. (0.1 mole), and 2-chloroquinoline, 32.7 g. (0.2 mole) was heated in 100 ml. of hexanol under reflux for 48 hours. The tan solid which appeared upon cooling was washed well with aqueous alkali. Recrystallization of the free amine from an ethanol-water mixture yielded 11.2 g. of white crystals, m.p. 195-196°. Analysis showed it to be the known 2-hydroxyquinoline.

Anal. Calcd. for C_9H_7ON: N, 9.66. Found: N, 9.70, 9.76. The picrate melted at 134°; literature m.p. 132° (Kent, et al, 3).

2-Aminoquinoline—The 2-aminoquinoline used to prepare the 1,3-di(2′-quinolyl)thiourea was made by the method of Elderfield (2) for 4-aminoquinoline. Gaseous ammonia was bubbled for 11 hours through a refluxing solution of 39.6 g. (0.24 moles) of 2-chloroquinoline in 226 g. (2.4 moles) of phenol. A solid remained in the flask until the end of

this period. The reaction mixture was cooled and poured into 900 g. of 10% NaOH solution. The yellow solid which separated was washed with water and recrystallized from benzene. 2-Aminoquinoline, 13.0 g., m.p. 128-129°, was obtained (37% yield).

2-Amino-6-Methoxyquinoline—Essentially the same procedure was employed in preparing the 6-methoxy analogue; however, a longer reaction time (24 hours) was used. Gaseous ammonia was bubbled for 24 hours through a refluxing solution of 44.7 g. (0.23 mole) of 2-chloro-6-methoxyquinoline in 226.1 g. (2.41 moles) of phenol. At the end of this time, the reaction was stopped, allowed to cool, and the reaction mixture poured into a solution of 115 g. of NaOH in a liter of water. The product which separated was washed with NaOH solution and several times with water. After recrystallizing from benzene, 20.6 g. of the white, crystalline 2-amino-6-methoxyquinoline, m.p. 179.5-181° were obtained (51% yield).

1,3-Di-(2′-quinolyl)thiourea—A mixture of 2-aminoquinoline, 12.6 g. (0.087 mole), carbon disulfide, 30 ml., and sulfur, 0.2 g., was refluxed for 21 days. A gas (H_2S) was evolved slowly throughout this period of time. The reaction mixture was cooled and filtered. The solid product was shaken with ethanol to dissolve the unreacted 2-aminoquinoline. The residue, after recrystallization from pyridine, melted at 214° and gave a positive test for sulfur after Na fusion. The yield was 5.1 g. of a white crystalline solid (35% theory). Analysis showed it to be 1,3-di-(2′-quinolyl)thiourea.

Anal. Calcd. for $C_{19}H_{14}N_4S$: N, 17.01. Found: N, 17.00.

1,3-Di-(2′-quinolyl)guanidine—The above thiourea, 4.5 g., was dissolved in 60 ml. of pyridine which had been previously saturated with ammonia gas. Basic lead carbonate, $2PbCO_3 \cdot Pb(OH)_2$, 25 g., was added, and ammonia was bubbled through the refluxing mixture for 15 hours. A small amount of the clear liquid was withdrawn and heated with fresh basic lead carbonate to test for completeness of reaction. Since no PbS precipitated, the entire mixture was filtered and the filtrate evaporated to 20 ml. The solid which separated on cooling was recrystallized from pyridine. Yield 0.11 g. (2.6% theory) of white crystals, m.p. 236°. Analysis showed it to be the desired product, 1,3-di-(2′-quinolyl)guanidine.

Anal. Calcd. for $C_{19}H_{15}N_5$: N, 22.35. Found: N, 22.25. The picrate prepared from a nitrobenzene solution decomposed at 284° (uncor.).

1,3-Di-(6′methoxy-2′-quinolyl)thiourea—A mixture of 2-amino-6-methoxyquinoline, 20.3 g. (0.12 mole), toluene, 200 ml., carbon disulfide, 40 ml., and sulfur, 0.2 g., was refluxed for 25 days on the steam bath. The odor of H_2S was detected even at the end of this period of time. The reaction was not run continuously, but was stopped twice during the course of the reaction, and the insoluble thiourea which had precipitated was filtered off. Also small amounts of carbon disulfide were added frequently to replace that lost by evaporation. The solid product

was separated and washed with ethanol to remove the unreacted aminoquinoline. All of the batches of thiourea collected were combined and recrystallized from pyridine. Yield, 8.5 g. (37% theory) of yellow, fine needles, m.p. 241.5-242°.

Anal. Calcd. for $C_{21}H_{18}O_2N_4S$: N, 14.35. Found: N, 14.41.

1,3-Di-(6′-methoxy-2′-quinolyl)guanidine—A solution of the above thiourea, 8.4 g. (.022 mole), in 150 ml. of pyridine was saturated with ammonia gas. Basic lead carbonate, 50 g., was added, and the mixture was heated with stirring at 112° for 7 hours. The gas was not passed through continuously but only intermittently for short periods of time. The warm reaction mixture was filtered, evaporated to 25 ml. and cooled. Recrystallization of the precipitated solid from pyridine gave 5.0 g. (62% theory) of white crystalline 1,3-di-(6′-methoxy-2′-quinolyl)-guanidine, m.p. 240.5-241.5°.

Anal. Calcd. for $C_{21}H_{19}O_2N_5$: N, 18.76. Found: N, 18.63. The conditions used in the above desulfurization were less drastic than those employed for the unsubstituted thiourea; viz., less ammonia and a shorter reaction time. This probably accounts for the greatly improved yield.

Summary

1,3-Di-(2′-quinolyl)guanidine and its 6,6′-dimethoxy derivative have been prepared from the corresponding 2-quinolylamines via the diquinolylthioureas. The guanidines as well as their hydrochlorides and nitrates were too insoluble to permit testing as antimalarials.

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3. KENT, A., MCNEIL, D., and COWPER, R. M. 1946. Compounds of polynitrosubstances with derivatives of carbostyril. J. Chem. Soc., **1946**:1860.
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Bromination of Phenylquinolines[1]

C. E. Kaslow and Sydney J. Nix, Indiana University

Although there are numerous references to work on bromination of quinolines in which there are present groups such as the hydroxy, methyl and so forth, no study has been made on the bromination of phenylquinolines. Recently, it was reported that the treatment of 3-bromo-4-hydroxy-2-phenylquinoline at an elevated temperature with an excess of phosphorus pentabromide gave a tetrabromo-2-phenylquinoline (4). It was also reported that a small amount of tribromo-2-phenylquinoline was obtained as a byproduct when 4-hydroxy-2-phenylquinoline was heated with excess phosphorus pentabromide. No attempt was made to identify either substance.

This work has been repeated under the same conditions as reported (4) but the high yield of polybrominated substances could not be obtained. When 3-bromo-4-hydroxy-2-phenylquinoline was treated with a large excess of phosphorus pentabromide, most of the product was identified as 3,4-dibromo-2-phenylquinoline with only small amounts of impure higher melting substances. The tribromo-2-phenylquinoline was proven to be incorrect since a mixed melting point determination with 3,4-dibromo-2-phenylquinoline showed no depression. In the present work, it was also shown that a small amount of 3,4-dibromo-2-phenylquinoline was actually produced when 4-hydroxy-2-phenylquinoline was heated with phosphorus pentabromide. Substitution of bromine into position 3 has been reported previously (5) when phosphorus pentabromide was used. The substitution could have occurred before replacement of the hydoxy group had taken place. When 4-bromo-2-phenylquinoline was heated with excess phosphorus pentabromide some 3,4-dibromo-2-phenylquinoline was produced; much starting material was recovered and some impure material of higher melting point was also obtained. Treatment of 3,4-dibromo-2-phenylquinoline in the same manner likewise did not yield polybrominated products which could be purified.

It was decided to investigate the action which anhydrous aluminum chloride might have on the bromination. When 3,4-dibromo-2-phenylquinoline was heated with the above catalyst in nitrobenzene, a mixture of polybrominated substances was obtained from which a pure tetrabromo-2-phenylquinoline was isolated in a rather low yield. A logical procedure as a part of the structure proof of the compound seemed to be oxidation. Thus oxidation of a 4-hydroxy-2-phenylquinoline should yield the corresponding N-benzoylanthranilic acid. A trial oxidation of 4-hydroxy-2-phenylquinoline by potassium permaganate in glacial acetic acid gave N-benzoylanthranilic acid but oxidation in dilute sodium carbonate solution gave only benzoic acid. When the oxidation was stopped before all of the hydroxy-quinoline was gone, it was possible

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[1] Contribution No. 534 from the Chemistry Laboratory of Indiana University.

to isolate some N-benzoylanthranilic acid. However oxidation of 3-bromo-2-phenyl-4-hydroxyquinoline in glacial acetic acid gave an inseparable mixture which upon saponfication yielded benzoic acid and 5-bromoanthranilic acid. The latter substance was identified through a mixed melting point determination with authentic 5-bromoanthranilic acid which was prepared according to the method of Wheeler and Oates (7). It is quite obvious that the bromine which was liberated during the oxidation reacted with the N-benzoylanthranilic acid yielding the 5-bromo derivative. When the bromoquinoline was axidized in sodium carbonate solution only benzoic acid could be isolated.

A trial hydrolsis of 3,4-dibromo-2-phenylquinoline showed it to be entirely resistant to boiling sodium hydroxide solution but on heating it in glacial acetic acid according to the method of Cutler and Surrey (1), replacement of the bromine atom in position 4 by the hydroxy group occurred readily. When 3,4,x,x-tetrabromo-2-phenylquinoline was heated in glacial acetic acid to give 4-hydroxy-3,x,x-tribromo-2-phenylquinoline then the latter substance oxidized by potassium permanganate in sodium carbonate solution, only m-bromobenzoic acid was isolated. No pure substance could be isolated from the oxidation in glacial acetic acid. Hydrolysis of the tribromo compound, then oxidation in sodium carbonate likewise gave only m-bromobenzoic acid. Thus, meta substitution in the 2-phenyl group is established.

Experimental

4-Hydroxy-2-phenylquinoline, 4-bromo-2-phenylquinoline and 3-bromo-4-hydroxy-2-phenylquinoline were prepared according to the method reported previously (4). Phosphoryl tribromide was prepared according to the method of Gerrard and coworkers (2); in the formation of the intermediate phosphorus pentabromide, it was found to be better to cool the stirred solution of phosphorus tribromide in petroleum ether while the bromine was being added.

3,4-Dibromo-2-phenylquinoline.—Five grams (0.017 mole) of 3-bromo-4-hydroxy-2-phenylquinoline was heated for one hour at 105° with 10 g. of phosphoryl tribromide, then the cold reaction mixture was added to 100 ml. of water and after standing thirty minutes, the solution was heated for a half hour. After cooling, it was made strongly alkaline with sodium hydroxide. The crude solid was removed by filtration, washed, then dried and finally refluxed with 150 ml. of ligroin (b.p. 60-90°). After the solution was filtered, the filtrate was concentrated to 50 ml. The 3,4-dibromo-2-phenylquinoline crystallized as white needles. The yield was 5.6 g. (88%), m.p. 149.5-150°.

Anal. Calc'd for $C_{15}H_9Br_2N$: Br, 44.08%. Found: Br, 44.43%

Action of Glacial Acetic Acid on 3,4-Dibromo-2-phenylquinoline.—One gram of 3,4-dibromo-2-phenylquinoline was dissolved in 12 g. of glacial acetic acid and the solution refluxed for two hours. After cooling, the solution was poured into 25 ml. of water, the solid removed and dried then extracted with 50 ml. of boiling ligroin. The insoluble portion (0.89 g.) was recrystallized from 45 ml. of absolute

ethyl alcohol, giving 0.45 g. of a white solid which melted at 275-278°. A mixed melting point determination with 3-bromo-4-hydroxy-2-phenylquinoline showed no depression.

2-(p-Bromophenyl)-4-hydroxyquinoline.—Ethyl p-bromobenzoylacetate was prepared in a 70% yield from p-bromobenzoyl chloride and ethyl acetoacetate in the manner described by Hale and Tharp (3). The ethyl p-bromobenzoylacetate (31 g.) was added to a solution of 11.2 g. (0.12 mole) of aniline in 150 ml. of carbon tetrachloride, two drops of dilute hydrochloric acid added and the solution refluxed under a condenser attached to a heavier-than-water liquid separater until the theoretical amount of water was collected. After removal of the carbon tetrachloride, the oil was dissolved in 25 ml. of diphenyl ether and the solution added to 100 ml. of boiling diphenyl ether. After cooling, the solid was removed by filtration and washed with a 50-ml. portion of benzene and two 50-ml. portions of ligroin, then the solid refluxed with 200 ml. of benzene. The residue (17.7 g.) was recrystallized from 380 ml. of pyridine yielding 15.5 g. of light yellow colored flakes. Recrystallation from n-butyl cellosolve gave a 40% yield of white solid which melted at 323-324°. The recorded (4) melting point is given as 320-321°.

3-Bromo-2-(p-bromophenyl)-4-hydroxyquinoline.—A stirred solution of 2.9 g. (0.01 mole) of 2-(p-bromophenyl)-4-hydroxyquinoline in 85 ml. of glacial acetic acid at 70° was treated with a solution of 2 g. (0.012 mole) of bromine in 10 ml. of glacial acetic acid, then heated on steam bath for ten minutes. The cold solution was diluted with 75 ml. of water containing 2 g. of sodium hydroxide the solid removed by filtration, washed and recrystallized from 100 ml. of methyl cellosolve. The yield was 3.1 g. (85%) of white solid which melted at 285.5-287°.

Anal. Calc'd for $C_{15}H_9Br_2NO$: Br, 42.22%. Found: Br. 42.72%.

3,4,4′-Tribromo-2-phenylquinoline.—This substance was prepared from 2.5 g. (0.0066 mole) of 3-bromo-2-(p-bromophenyl)-4-hydroxyquinoline in a manner exactly analogous to the method for the preparation of 3,4-dibromo-2-phenylquinoline. The yield of crude substance was 2.6 g. (91%). A portion of the solid was recrystallized from absolute ethyl alcohol, giving light, fluffy needles which melted at 222.8-223.8°.

Anal. Calc'd for $C_{15}H_8Br_3N$: Br, 54.29%. Found: Br, 54.49%.

N-(m-Bromobenzoyl)-5-bromoanthranilic Acid.—The preparation of this substance was based on a general procedure of Steiger (6). A solution of 3.5 g. (0.016 mole) of 5-bromoanthranilic acid (7) in 81 ml. of 2 N sodium hydroxide was placed in a 3-necked flask and the solution cooled to 0-1°. While the solution was stirred and kept cold, 3.6 g. (0.016 mole) of m-bromobenzoyl chloride and 8.1 ml. of 2 N sodium hydroxide were added simultaneously. The solution was stirred for thirty minutes while it warmed to room temperature. The sodium N-(bromobenzoyl)-5-bromoanthranilate was removed by filtration. The salt was added to 200 ml. of water, enough 5 N hydrochloric acid added to be in excess and the mixture stirred vigorously for thirty minutes. The yield of crude acid was 4.7 g. (76%); m. p., 236.5-239°. Recrystallization from absolute ethyl alcohol raised the melting point to 245-247°.

Anal. Calc'd for $C_{14}H_9Br_2NO_3$: Br, 40.10%. Found: Br, 40.05%.

Bromination of 3,4-Dibromo-2-phenylquinoline.—A. A mixture of 20 g. (0.055 mole) of 3,4-dibromo-2-phenylquinoline, 29 g. (0.22 mole) of anhydrous aluminum chloride and 55 g. (0.45 mole) of nitrobenzene was heated on a steam bath in a two-necked flash fitted with a condenser and dropping funnel. The contents were protected against moisture. Bromine (35.6 g., 0.22 mole) was added dropwise over a period of fourteen hours and the heating was continued for another ten hours. The red-colored reaction mixture was poured into 100 ml. of water, decolorized with sodium bisulfite and the nitrobenzene removed by steam distillation. The nondistillable solid was dried and extracted by refluxing twice with 300-ml. portions of ligroin. A yield of 10.3 g. of light pink solid was obtained from the ligroin. After recrystallization from absolute ethyl alcohol, the yield of solid was 7.7 g., m.p. 170-178°. Alternate recrystallization of 1.5 g. of the substance from absolute ethyl alcohol and from ethyl carbitol finally gave 0.2 g. of white flaky solid which melted at 179-181°.

Anal. Calc'd for $C_{15}H_7Br_4N$: Br, 61.42%. Found: Br, 61.50%.

B. A mixture of 10 g. (0.028 mole) of 2-phenyl-3,4-dibromoquinoline, 14.7 g. (0.11 mole) of anhydrous aluminum chloride, 27.7 g. (0.23 mole) of nitrobenzene and 9 g. (0.055 g.) of bromine were sealed in a pyrex carius tube and heated at 100° for 24 hours. After removal of the nitrobenzene by steam distillation, the dried residue was extracted with 350 ml. of boiling ligroin, yielding 6.1 g. of solid which melted at 164-174°. Recrystallization did not raise the melting point nor shorten the range appreciably.

Action of Glacial Acetic Acid on Bromination Product, B.—Four and nine-tenths grams of the product from B which melted at 166-175° was dehalogenated by treatment with glacial acetic acid as described previously. The yield of solid was 4.7 g.; recrystallization of the substance from 220 ml. of absolute ethyl alcohol gave 1.7 g. of solid which melted at 270-270.5°. A mixed melting point determination with 3-bromo-4-hydroxy-2-phenylquinoline (m.p. 278.5-280°) was 249-275°.

Anal. Calc'd for $C_{15}H_9Br_2NO$: Br, 42.22%. Found: Br. 41.12%.

Oxidation of 3,x-Dibromo-4-hydroxy-2-phenylquinoline.—Five-tenths gram of the above substance, obtained when the bromination product B was refluxed with glacial acetic acid, was heated with 25 ml. of 10% sodium carbonate solution while 2.5 g. of potassium permanganate was added portionwise. After two hours, the solution was clarified with sodium bisulfite and the hot solution acidified with hydrochloric acid. The white precipitate was removed and recrystallized from boiling water. The yield of solid was 0.05 g., m.p. 149-153°. A mixed melting point determination with m-bromobenzoic acid showed no depression.

When 1 g. of the crude tetrabromo compound, 2-phenyl-3,4,x,x-tetrabromoquinoline, of somewhat shorter melting range was heated with glacial acetic acid, then the resulting crude tribromo-4-hydroxy-2-phenlyquinoline oxidized with potassium permanganate in sodium carbonate solution, only m-bromobenzoic acid was isolated.

Oxidation of 3-Bromo-4-hydroxy-2-phenylquinoline.—A solution 7 g. of 3-bromo-4-hydroxy-2-phenylquinoline in 100 ml. of glacial acetic acid

was refluxed while 13 g. of potassium permanganate was added portionwise over a period of 2.5-3 hours. The solution was poured into 300 ml. of water, decolorized with sodium bisulfite and the tan colored precipitate removed. The solid was refluxed for two hours with 50 ml. of 5% sodium hydroxide solution, then solution treated with 2 g. of Norite and filtered. The alkaline filtrate was neutralized with concentrated hydrochloride acid, then the addition continued until no more solid seemed to redissolve. After filtering, the solution was carefully neutralized with sodium hydroxide and the solid removed. After three recrystallizations from benzene and toluene and finally from water there was obtained a light colored solid which melted at 207.5-209°. A mixed melting point determination with 5-bromoanthranilic acid (m.p. 209-209°) showed no depression.

Summary

Bromination of 3,4-dibromo-2-phenylquinoline in nitrobenzene using anhydrous aluminum chloride introduced a bromine atom in meta position in the phenyl group. It was shown that oxidation of a 3-bromo-4-hydroxyquinoline in acetic acid solution gave a bromoanthranilic acid. The preparation of 3,4-dibromo-2-phenylquinoline, 3,4,4′-tribromo-2-phenylquinoline, 3-bromo-2-(p-bromophenyl)-4-hydroxyquinoline and N-(m-benzoyl)-5-bromoanthranilic acid is described.

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The Preparation of Aromatic Esters of Malonic Acid[1]

JOHN H. BILLMAN, R. VINCENT CASH[2] and ELEANOR K. WAKEFIELD

The preparations of four aromatic esters of malonic acid have been described in the literature. These are the diphenyl-, di-β-naphthyl-, di-p-tolyl-, and di-p-nitrophenyl malonates.

The preparation of diphenyl malonate by Bischoff and von Hedenström (5) in 1902 illustrates one of the synthetic methods employed. Phenol and malonyl chloride were warmed on a water bath for a short time; hydrogen chloride was envolved and the solid ester crystallized on cooling.

$$\mathrm{Cl\text{-}\overset{\overset{\cdot\cdot}{O}}{\overset{\cdot\cdot}{C}}\text{-}CH_2\text{-}\overset{\overset{\cdot\cdot}{O}}{\overset{\cdot\cdot}{C}}\text{-}Cl} + 2\ C_6H_5OH \rightarrow \mathrm{C_6H_5\text{-}O\text{-}\overset{\overset{\cdot\cdot}{O}}{\overset{\cdot\cdot}{C}}\text{-}CH_2\text{-}\overset{\overset{\cdot\cdot}{O}}{\overset{\cdot\cdot}{C}}\text{-}O\text{-}C_6H_5} + 2\ HCl$$

These workers tried without success to prepare this ester from malonic acid, phenol, and thionyl chloride. However, Auger and Billy (1) were able to synthesize diphenyl malonate from malonic acid, phenol, and phosphorus oxychloride.

Guia (6) obtained di-β-naphthnyl malonate rather than the desired counmarin-type compound when he heated β-naphthol, malonyl chloride, and aluminum chloride in carbon disulfide. Backer and Lolkema (2) synthesized di-p-tolyl malonate and di-p-nitrophenyl malonate from malonyl chloride according to the above equation. The latter ester was also prepared by these investigators by treatment of the diphenyl malonate with nitric acid at 0°.

Since carbon suboxide has been reported (7) to react with alcohols to yield dialkyl malonates, it seemed of interest to attempt to extend the reaction to phenols.

$$O{=}C{=}C{=}C{=}O + 2\ HOAr \rightarrow \mathrm{Ar\text{-}O\text{-}\overset{\overset{\cdot\cdot}{O}}{\overset{\cdot\cdot}{C}}\text{-}CH_2\text{-}\overset{\overset{\cdot\cdot}{O}}{\overset{\cdot\cdot}{C}}\text{-}O\text{-}Ar}$$

Five phenols were successfully esterified with carbon suboxide, with sulfuric acid or p-toluenesulfonic acid present at catalyst. Salicylic acid did not esterify and was quantitatively recovered.

As a check on their structure it seemed desirable and of interest to prepare some of these diaryl malonates directly from malonic acid.

$$\mathrm{HO\text{-}\overset{\overset{\cdot\cdot}{O}}{\overset{\cdot\cdot}{C}}\text{-}CH_2\text{-}\overset{\overset{\cdot\cdot}{O}}{\overset{\cdot\cdot}{C}}\text{-}OH} + 2\ HOAr \rightarrow \mathrm{Ar\text{-}O\text{-}\overset{\overset{\cdot\cdot}{O}}{\overset{\cdot\cdot}{C}}\text{-}CH_2\text{-}\overset{\overset{\cdot\cdot}{O}}{\overset{\cdot\cdot}{C}}\text{-}O\text{-}Ar} + 2\ H_2O$$

Sulfuric acid or p-tolunesulfonic acid was used as a catalyst. The reaction was carried out in refluxing toluene so as to remove the water as it formed. By this second method, four aromatic esters of malonic

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acid were prepared. These esters were identical with esters prepared from carbon suboxide (Table I).

TABLE I. Diaryl Malonates

Phenol	Method	Catalyst	Ester m.p., °C	Yield %
Phenol	I	H_2SO_4	49-50	90.0
o-Cyclohexylphenol	I	pTSA[b]	134-135	37.6
	II	H_2SO_4	134-135	5.1
β-Naphthol	I	H_2SO_4	142-142.5	94.0
	II	H_2SO_4	144-145[c]	3.4
p-Nitrophenol	II	H_2SO_4	198.5-200[d] dec	1.2
	I	H_2SO_4		87.6
p-Phenylpherol	I	pTSA	199-200[e]	5.5
	II	pTSA	199-200	21.5
	II	H_2SO_4	199-200	8.8

[b]pTSA—p-Toluenesulfonic acid. Analysis of ester Calcd. for $C_{27}H_{32}O_4$: C, 77.11; H. 7.67. Found: C, 77.09; H, 7.10.

[c]Giua (6) found 146-147°.

[d]Backer and Lolkema (2) 202-203° dec.

[e]Analysis of ester Calcd. for $C_{27}H_{20}O_4$: C, 79.40; H, 4.94. Found: C, 79.44; H, 5.16.

Experimental

Carbon Suboxide. This reagent was prepared by the pyrolysis of diacetyltartaric anhydride similar to the procedure reported in a previous publication (3). However, the apparatus was improved by the inclusion of an electrical condenser-precipitator as described by the authors (4). The carbon suboxide produced was carefully distilled and collected in anhydrous ether in a flask surrounded by dry-ice an acetone. The concentration, as shown by the weight of malonanilide precipitated from an aliquot portion of the solution, corresponded to one gram of carbon suboxide per 4.3 ml. of solution. From 635 grams of diacetyltartaric anhydride, 69 grams (34%) of carbon suboxide were obtained.

Diaryl Malonates (Method I). Each phenol (0.044 mole) was dissolved in as little anhydrous ether as was needed for solution, and either four drops of concentrated sulfuric acid or a pea-size crystal of p-toluenesulfonic acid was added to this solution in a pressure bottle. After the sealed bottle had been cooled in the refrigerator, 1.5 grams (0.022 mole) of carbon suboxide in 6.5 ml. of the ether solution was added from a buret. The buret was kept cold by a jacket containing an ice-salt mixture, and the ether solution was added to the buret by means of a siphon. The sealed pressure bottle was kept in the refrigerator for three days and then permitted to warm to room temperature.

No odor of carbon suboxide was observed when the bottle was opened. The ether was allowed to evaporate, and the residue was dissolved in hot 95% ethanol. A few drops of water were added and the solution cooled. The solid which separated was recrystallized from toluene or a second time from aqueous ethyl alcohol.

Diaryl Malonates (Method II). The apparatus consisted of a 500-ml. round-bottom flash, surmounted by a Dean-Stark tube and a water-cooled reflux condenser. All connections were by means of ground glass joints. A plug of absorbent cotton was placed in the open end of the condenser tube to exclude atmospheric moisture. The flask was heated over a hot-plate.

In the flask were placed 10.4 grams (0.1 mole) of malonic acid, the required weight (0.22 mole) of the phenol, and 300 ml. of anhydrous toluene. The mixture was refluxed briefly to dissolve the solids, and then the catalyst (four drops of concentrated sulfuric acid or a small crystal of p-toluenesulfonic acid) was added. Refluxing was continued (several days) until the water level in the Dean-Stark tube no longer rose. The solution was then concentrated to about 75 ml. and cooled. The solid product which separated was washed with ether and recrystallized from toluene, adding a small volume of petroleum ether after the material had dissolved. Two or three such recrystallizations were required. The di-p-nitrophenyl malonate was recrystallized from glacial acetic acid.

Summary

Two new methods have been developed for the synthesis of aryl esters of malonic acid. One method employs carbon suboxide and a phenol; the other malonic acid and a phenol. The carbon suboxide method produces the esters in high yields.

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The Isothermal Salt Effect in the Iodine Clock Reaction[1]

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In studies on the iodine clock or Landolt reaction Skrabal (1) observed that the addition of sodium sulfate to the mixture caused a negative temperature coefficient in the time of reaction, T. Other workers (2, 3, 4) found that T was also affected at constant temperature by the presence of added halides and reducing agents, entities entering the actual chemical reactions involved. Only one instance of the isothermal effect of a presumably chemically inert salt, potassium nitrate, on T has been found in the literature (4). For this case T was found, in general, to increase (at a decreasing rate) with increasing molarity of the mixture in added salt. However, in one short series of experiments (apparently overlooked by the authors) a definite maximum occurred in the data for T as a function of the molarity of added salt. The present paper reports the extension of studies on the isothermal salt effect to usage of lithium, sodium, potassium and magnesium sulfates.

Experimental

The following standard aqueous solutions were prepared: 2.336×10^{-2} M c. p. potassium iodate, soluble starch (10 g. per liter), 5 N sulfuric acid and 3.1733×10^{-2} M c. p. anhydrous sodium sulfite (4.0000 g. per liter). The sulfite solution, made up fresh just before use, was never kept for more than three hours. The starch suspension was prepared at intervals as needed while the iodate solution, as well as the acid solution, was made in one large batch sufficient for use in all runs. Lithium, sodium, potassium, and magnesium sulfate stock solutions of desirable concentrations were prepared from weighed quantities of the appropriate c. p. or U. S. P. grade (latter grade used only for some of the magnesium sulfate solutions) compounds and the concentrations were checked by comparison of the observed densities with those reported previously (5).

A series of runs was made for each sulfate stock solution. For this series, a standard oxidant stock solution was prepared by mixing 100 ml. of acid, 250 ml. of the iodate, 150 ml. of the starch suspension and sufficient water and/or sulfate stock solution (measured volume) to give a total volume of one liter. Individual oxidant samples in the series were prepared in advance from 50 ml. of standard oxidant stock solution, x ml. (measured) of sulfate stock solution and (150 — x) ml. of water and were kept in stoppered flasks. For a particular run, the oxidant sample was transferred to a one-liter beaker and its temperature was adjusted to 25 ± 1° C. A reductant sample was then prepared separately by mixing 25 ml. of the sulfite solution, y ml. (measured)

[1] Contribution No. 540 from the Chemistry Laboratory of Indiana University.

of the same sulfate stock solution, (170 — y) ml. of water and (after adjustment of the temperature as before) 5 ml. of the acid. The reductant sample was stirred vigorously for two or three seconds and poured rapidly into the oxidant. The mixture was stirred for five to seven seconds and then allowed to stand until the dark blue color developed.

For T less than thirty seconds development of the color was visually instantaneous throughout the solution and reproducibility was ± 0.3 seconds. For T more than about thirty seconds, appearance of a thin overlying dark blue layer in the solution preceded the homogeneous color change by as much as several seconds and the main coloration proceeded at a visually perceptible rate. For these greater values of T reproducibility was ± 0.6 seconds. All solutions used appeared clear except for those containing the higher concentrations of magnesium sulfate. The temperature of the mixture (checked after coloration) was 25.0 ± 0.2° C. in every case. Duplicate runs were usually made.

Results and Discussion

Comparative data for the effects of the four metallic sulfates used (in concentrations up to .47 M) are given in Table I. Since the three alkali sulfates were equivalent in their effects (within experimental error), data for higher salt concentrations were secured only for sodium and magnesium sulfates. From complete data for these two salts (Fig. 1), one observes that at least up to concentrations of 0.8 M

TABLE I. Effect of Concentration of Solution in Added Sulfate on Time of Reaction, T

Ml. of 0.622 M Sulfate Used in Sample*	T (in seconds) for Use of			
	Li_2SO_4	Na_2SO_4	K_2SO_4	$MgSO_4$
0	14.8	15.0	15.2	15.2
50	26.2	25.8	25.2	23.6
150	42.8	43.4	41.8	34.6
200	48.8	49.2	47.2	38.4
300	55.8	57.0	56.4	42.2

*Total volume of sample, 400 ml.

the time of reaction, T, increases, but at a decreasing rate, with increasing concentration of added salt, or, that is, with increasing ionic strength, μ, of the solution. The magnesium ion, however, is less effective than two sodium ions in regard to lengthening T. This difference is not explainable simply in terms of ionic strength, for on this basis alone the magnesium ion should be the more effective. Since Eggert has found (2) that T varies inversely as the approximate square of the hydrion concentration, it is possible that the overall salt effects observed here are the results of two opposing factors, namely (a) the

ionic strength or primary salt effect tending to cause T to increase with increasing molarity in all cases and (b) hydrolysis of the salt (a secondary salt effect) causing an increase in the hydrion concentration and tending to cause T to decrease with increasing molarity. Hydrolysis should be operative only in the case of the magnesium salt where it might be sufficiently extensive as to overcompensate for the anticipated larger (as compared to the effect of the sodium salt) primary salt effect.

As one can see in Figure 1 or even more strikingly in Figure 2, a definite maximum is present in the curve for magnesium sulfate. Unfortunately the lower molar solubility of sodium sulfate prevented

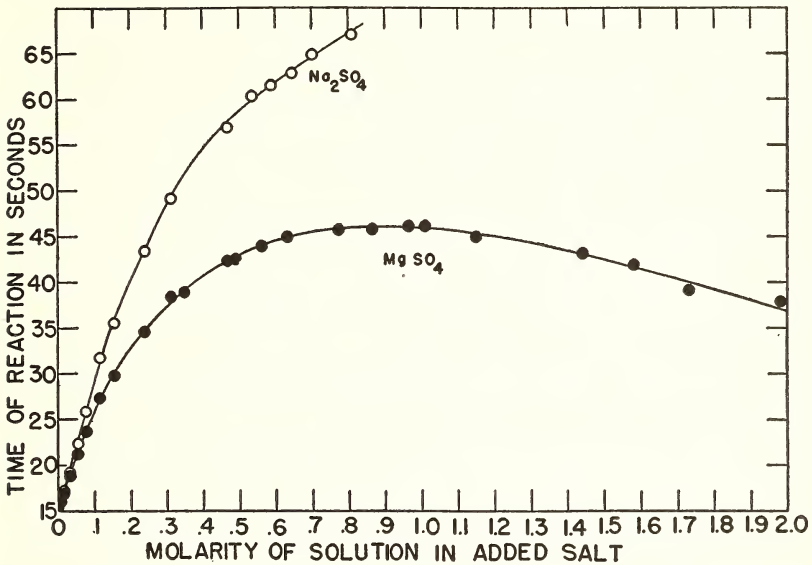

Fig. 1. Molarity of solution in added salt plotted against time.

further extension of data in order to search for such a maximum in the other curve. Information available for the salt potassium nitrate (4), indicates that this maximum is not a peculiarity associated with the magnesium ion, and, hence, may be a primary salt effect. This supposition gains plausibility when one examines the situation somewhat quantitatively.

As the result of some excellent experimental and theoretical endeavors by various people, Eggert (2, 3) proposed three major steps to the overall Landolt reaction. These are

$$3\ SO_3^{-2} + IO_3^- \xrightarrow{k_1} 3\ SO_4^{-2} + I^- \qquad \text{(Step 1)}$$

$$5\ I^- + IO_3^- + 6\ H^+ \xrightarrow{k_2} 3\ I_2 + 3\ H_2O \qquad \text{(Step 2)}$$

$$I_2 + SO_3^{-2} + H_2O \xrightarrow{k_3} 2\ I^- + SO_4^{-2} + 2\ H^+, \qquad \text{(Step 3)}$$

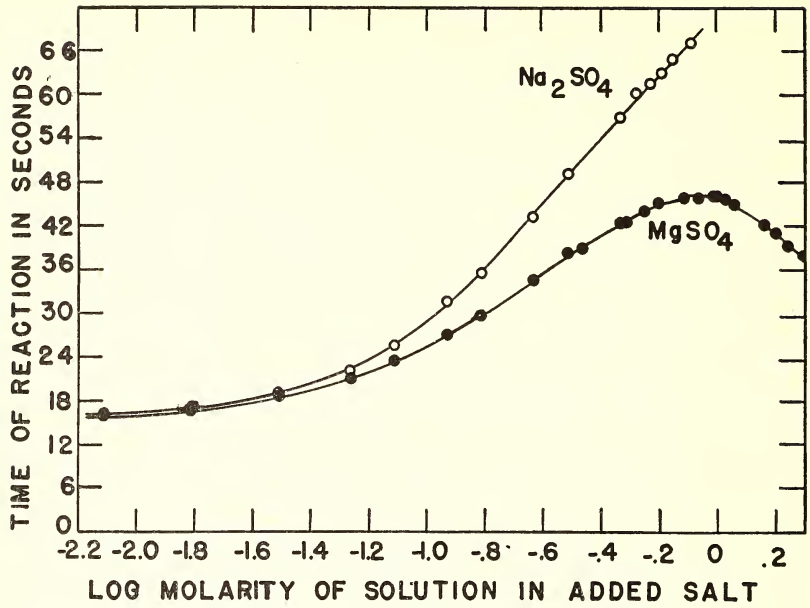

Fig. 2. Log molarity of solution in added salt plotted against time.

where the k's are the specific rate constants for the respective steps and $k_3 >> k_2 > k_1$. He found, moreover, that T was satisfactorily given by the semiempirical equation,

$$T = \frac{1}{k_2 - k_1} \ln \frac{k_2}{k_1} \quad . \qquad \text{(Equation 1)}$$

The effect on k of varying μ can be ascertained theoretically. Thus, for the reaction $A + B \rightleftarrows X \rightarrow$ Products, where A and B are the simplest entities involved in the rate-determining step of the reaction and X is the activated complex formed, k is given by the expression (6)

$$k = m \frac{f_A f_B}{f_X} \quad , \qquad \text{(Equation 2)}$$

where m is a positive constant and the f's are the corresponding activity coefficients. Taking natural logarithms of both sides of equation 2 gives

$$\ln k = \ln m + \ln \frac{f_A f_B}{f_X} \quad . \qquad \text{(Equation 3)}$$

The last term of equation 3 can be evaluated from the expression for the complete Debye-Hückel theory (7)

$$\ln f = a \mu - \frac{b z^2 \mu^{1/2}}{1 + c\mu^{1/2}} \quad , \qquad \text{(Equation 4)}$$

where a, b and c are positive constants and z is the electrical charge on the entity under consideration (A, B or X). Substituting $\mu^{1/2} = v$ in equation 4 and making use of the relationship $z_X = z_A + z_B$, one obtains

$$\ln \frac{f_A f_B}{f_X} = av^2 + \frac{2\, bz_A z_B v}{1 + cv} \quad \text{(Equation 5)}$$

Assuming that z_A and z_B are both negative for step 1 but opposite in sign for step 2, one finds (from equations 3 and 5)

$$\ln k_1 = \ln m_1 + av^2 + \frac{b_1 v}{1 + cv} \quad \text{(Equation 6)}$$

$$\ln k_2 = \ln m_2 + av^2 - \frac{b_2 v}{1 + cv}, \quad \text{(Equation 7)}$$

where m_1, b_1, m_2 and b_2 are positive constants. Substituting for k_1 and k_2 from equations 6 and 7 in equation 1, one obtains

$$T = \frac{\ln \dfrac{m_2}{m_1} - \dfrac{(b_1 + b_2)v}{1 + cv}}{\exp av^2 \left[m_2 \exp\left(-\dfrac{b_2 v}{1 + cv} \right) - m_1 \exp\left(\dfrac{b_1 v}{1 + cv} \right) \right]} \quad \text{(Equation 8)}$$

Evaluation of the limits for equation 8 shows that $\lim_{v \to 0} T = \lim_{\mu \to 0} T =$ a constant (as observed) and $\lim_{v \to \infty} T = \lim_{\mu \to \infty} T = 0$.

For small values of v (i. e. for dilute solution) equations 6 and 7 reduce to the simpler expressions

$$\ln k_1 = \ln m_1 + b_1 v \text{ and } \ln k_2 = \ln m_2 - b_2 v$$

Hence, for this situation, k_1 increases with increasing μ while k_2 decreases simultaneously. These combined variations should cause T to increase with increasing μ (in dilute solution) since the increasing factor $\left(\dfrac{1}{k_2 - k_1} \right)$ of equation 1 will overwhelm the influence of the decreasing factor $\left(\ln \dfrac{k_2}{k_1} \right)$. This consideration, coupled with those of the previously evaluated limits of T for infinitely dilute and infinitely concentrated solutions and the assumption that T is a continuous function of μ throughout this range, necessitates (in theory) the presence of at least one maximum in each curve for T versus concentration of added chemically inert salt.

Further experimentation is planned in an effort to elucidate this salt effect and to test the mechanistic details postulated here.

Summary

Lithium, sodium, potassium and magnesium sulfates have been found to increase the time of the iodine clock reaction at constant temperature when added in concentrations up to at least .47 M. Mole for mole the three alkali sulfates were equally effective. The curve of time versus concentration for the less effective magnesium sulfate showed a maximum. Interpretations of the results in terms of primary and secondary salt effects are presented.

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The Catalytic Activity of the Reduced Vanadates of Nickel, Copper and Lead[1]

C. S. Rohrer, P. F. King and O. W. Brown, Indiana University

Metals and their oxides have been studied by many investigators and have been classified in the order of their activities as reducing catalysts in a number of reactions. Numerous additional investigations have been made as to the effect of various addition agents on the activity, modifications and structure of these catalysts. One of the most intimate and homogeneous alterations possible, in separating the catalyst atoms or altering their structure, should be made by the addition of a non-metallic oxide to the metallic oxide catalyst such that a salt is formed. Yet there have been few studies on these compounds, or the metals formed by the reduction of these salts, as reducing catalysts.

This paper is one of a series reporting on the activity of such reduced salts as catalysts for the vapor phase reduction of organic nitro compounds to their respective amines with hydrogen. It is hoped that the series will lead to a better understanding of the effect of these anions in modifying the activity of a catalyst and aid in predicting the behavior of an untried catalyst.

Apparatus

A vertical-type aluminum block furnace, electrically heated, thermally controlled, and containing a pyrex-glass reaction tube of 18 mm. bore was employed. Temperature was recorded by means of thermocouples extending 2 inches into each end of a 12-inch catalyst column and a third extending well into the metal block. Feed was from above, controlled by the delivery of 2.00 ml. of nitrobenzene under a variable head of mercury through a calibrated capillary tube. Hydrogen was measured in liters per hours through a calibrated flowmeter.

Catalyst

The catalysts were reduced salts as prepared by Christena (2). Fifteen grams of each salt was supported on enough asbestos fiber to give a 12 inch catalyst bed. It was then reduced under a flow of 14.5 liters of hydrogen per hour in the following manner: nickel vanadate was brought to a temperature of 300° and maintained there for one hour, copper vanadate was brought to a temperature of 340° in one hour and four minutes and maintained at that temperature for one hour, while lead vanadate was brought to a temperature of 360° in

[1] Contribution No. 543 from the Chemical Laboratories of Indiana University.

one hour and fifteen minutes and maintained there for two additional hours.

Reduced Nickel Vanadate Catalyst

The operating conditions for curve No. 1, Figure 1 were 2 grams per hour of nitrobenzene and 230 per cent theory of hydrogen flowing

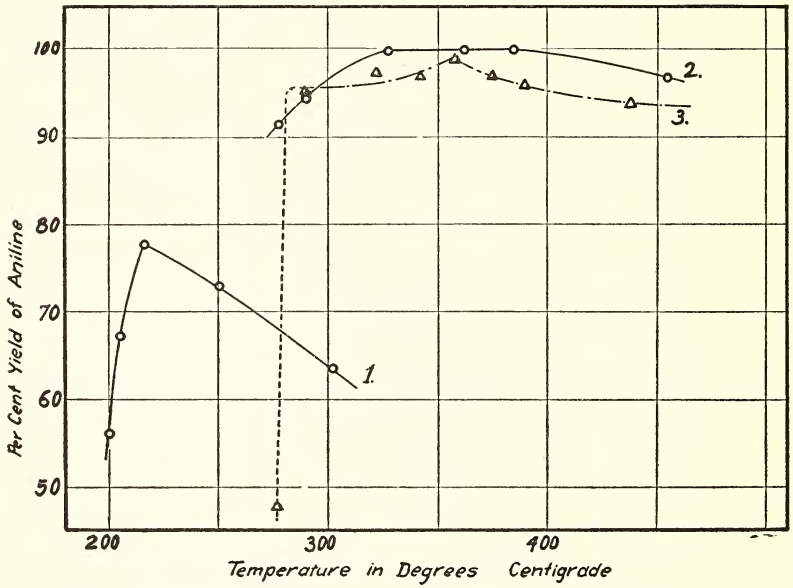

Fig. 1. The effect of operating temperature on yield of aniline. Curve 1, nickel vanadate; curve 2, copper vanadate; curve 3, lead vanadate.

over 15 grams of nickel vanadate reduced. We see the optimum furnace temperature of 216° agrees well with the 210° reported by Christena (2) for the reduction of nitronaphthalene.

A rate of 20 grams of nitrobenzene per hour gave the highest yields in percentage conversion, Table IA.

The optimum rate of flow of hydrogen, 230 per cent of theory, Table IB, is much less than the 700 to 1020 per cent of theory reported (2) for the reduction of α-nitronaphthalene.

It appears the activity of nickel vanadate is not high for the reduction of organic nitro compounds to their respective amines. This is due to its high activity as a reducing catalyst as we evidenced by the strong odor of benzene in the reduction products throughout the experiments.

X-ray powder defraction patterns revealed the reduced catalyst contained metallic nickel. There were, however, no lines corresponding to either V_2O_3 or V_2O_5. From the results of similar studies on other reduced compound catalysts in this laboratory (3, 4) we are led to

TABLE I. Catalyst, 15 grams of Nickel Vanadate Reduced; Furnace Temperature 235° C.

	Nitrobenzene gms/hr.	Hydrogen in per cent theory	Aniline in per cent yield
A	16	230	58.5
	20	230	75.0
	26	230	70.0
	32	230	57.5
B	20	184	50.0
	20	230	75.0
	20	294	74.0
	20	368	72.5

suspect that the remainder of the material is a salt of nickel oxide and one or more of the lower oxides of vanadium.

Reduced Copper Vanadate Catalyst

Quantitative yields of aniline may be produced over this catalyst in a range of from 325° to 385°, Figure 1 curve 2. The conditions for the construction of this curve were 9 grams of nitrobenzene and 408 per cent of hydrogen flowing over 15 grams of the nickel vanadate reduced. Here again there is good agreement with the temperature 320° to 340° reported for the maximum conversion of α-nitronaphthalene **(2)**.

The optimum rate for the flow of nitrobenzene is seen, Table IIA, to be from 9 to 5 or less grams per hour.

Hydrogen flowing at the rate of 408 per cent of theory was found to give the maximum yield, Table IIB, however yields above 97 per cent were obtained over the entire range studied.

TABLE II. Catalyst, 15 grams of Copper Vanadate Reduced; Furnace Temperature 325°

	Nitrobenzene gms/hr.	Hydrogen in per cent theary	Aniline in per cent theory
A	5	408	100.0
	9	408	100.0
	13	408	96.5
	18	408	93.5
B	9	257	97.5
	9	408	100.0
	9	612	98.9
	9	817	97.5
	9	1220	97.3

TABLE III. Catalyst, 15 grams of Lead Vanadate Reduced; Furnace Temperature 358° C.

	Nitrobenzene gms/hr.	Hydrogen in per cent theory	Aniline in per cent of theory
A	1.0	367	99.0
	1.5	367	99.0
	2.0	367	99.1
	3.0	367	98.9
	3.8	367	98.4
	7.0	367	97.8
B	2	184	99.0
	2	275	98.5
	2	367	99.1
	2	550	99.0
	2	698	99.0

It is of interest to note in the study of this catalyst that excellent reductions are obtained over broad ranges for each of the variables studied.

Reduced Lead Vanadate Catalyst

The optimum temperature for the reduction of nitrobenzene over this catalyst is seen to be approximately 358°, Figure 1 curve 3. The operating conditions for establishing this curve were 4 grams of nitrobenzene and 367 per cent theory of hydrogen flowing over 15 grams of lead vanadate reduced. Christena (2) reports an optimum temperature of 390° for the reduction of α-nitronaphthalene over the same catalyst. This difference may be in part due to the fact that the temperature used to reduce the catalyst in this work was 75° lower than that used by Christena. It is also seen in this work that in the temperature range from 320° to 375° the yields are above 97 per cent. At temperatures somewhere below 280° the catalyst began to lose activity slowly due to poisoning. Large quantities of azoxybenzene were also produced at these low temperatures.

Maximum yields are obtained when the rate of flow of nitrobenzene is less than 4 grams per hour and yields are constant at least to 1 gm as shown in Table IIIA. This curve was terminated at 1 gram per hour since duplicate values and constant rates were increasingly difficult to obtain at the lower values.

It is also noted that a very wide range in the rate of flow of hydrogen gave the maximum yield of 99 per cent aniline, Table IIIB.

So far as could be determined by X-ray powder defraction patterns the reduced catalyst consisted of metallic lead and vanadium trioxide.

The highest yield previously reported (1) for aniline prepared by reduction of nitrobenzene over lead or a lead compound was 98.4 per cent obtained by Brown and Raines over lead sulfide.

Summary

1. The optimum conditions for the reduced nickel vanadate catalyst were an operating temperature of 216°, hydrogen flowing at a rate of 230% of theory and nitrobenzene flowing at a rate of 20 grams per hour, giving a yield of 75 per cent aniline.

2. Reduced nickel vanadate is too active as a reducing catalyst for the intermediate reduction to aniline.

3. The optimum conditions for the reduced copper vanadate catalyst were temperatures from 325° to 385°, hydrogen flowing at a rate of 408 per cent of theory and nitrobenzene flowing at a rate of 5 to 9 grams per hour, giving a yield of 100 per cent aniline.

4. The optimum conditions for the reduced lead vanadate catalyst were 358°, hydrogen flowing in a range of from 184 to 698 per cent of theory or possibly a greater range, and nitrobenzene flowing at a rate of one gram per hour or less up to 3 grams per hour, giving yields of 99.0%. At nitrobenzene rates as high as 7 grams per hour the yield is 97.8 per cent.

5. Reduced lead vanadate gives yields greater than any previously reported where lead or lead compounds are used as catalysts.

6. While reduced copper vanadate is the best of the three catalysts studied for the reduction under consideration, both the copper and lead vanadates gave excellent yields over a rather wide range of the variables studied.

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ENTOMOLOGY

Chairman: J. A. Clark, Indianapolis

F. N. Young, Indiana University, was elected chairman for 1952.

ABSTRACTS

Relative attractiveness of different wavelengths of radiant energy to flying insects. H. O. Deay, J. G. Taylor, and M. T. Orem, Purdue University.—During the 1951 season eleven different wavelengths of radiant energy, ranging from those in the far ultraviolet to the infrared region of the electromagnetic spectrum, were compared as to their attractiveness to flying insects. In general the results show that the number and variety of insects attracted increased as the wavelengths decreased to about 3200 Angstrom units in length and then decreased at wavelengths shorter than 3200 A.

Tests of new insecticides for control of the meadow spittlebug. Ray T. Everly, Purdue University.—The emulsifiable form of fourteen insecticides were applied as low gallonage sprays on May 13 to Kenland red clover to study their toxicity to nymphs of the meadow spittlebug. BHC (benzene hexachloride) lindane, and toxaphene continued to give good control. Dieldrin, methoxychlor, and compound 269 (Julius Hyman Company) also gave good control. The systemic and other phosphorus compounds including EPN-300, Miticide, Systox, Potassan, Pestox-3, and Compound 4049 (American Cyanamid Co.), were ineffective in controlling the spittlebug. Control evaluations were made on visual observations, counts of nymphs per square foot, and adults per 10 sweeps of a 12 inch net. All methods of evaluation gave the same relative results for the insecticide tested.

The wireworm problem in Indiana. George E. Gould, Purdue University.—Wireworms have been one of the few major agricultural pests in Indiana for which no satisfactory control has been known. Studies initiated in 1951 indicated that corn was the most seriously affected crop, although damage was observed on wheat, tobacco and some vegetable crops, especially potatoes, onions and melons. A survey of the state indicated higher losses in the northern counties and especially on muck soils. To date the larvae of three genera of Elaterid beetles have been identified, namely *Melanotus, Limonius* and *Agriotes.* Some fields in the Kankakee river region were so heavily infested and corn stands so reduced that they were planted to soybeans. Corn was found to be destroyed in three ways: destruction of the germinating seed; cutting the tap root of newly-emerged plants; and the cutting of the unelongated stem in the crown of plants up to 15 inches

in height. Larger plants with a well-established root system were seldom killed. Of the seven materials tested as seed protectants for corn, lindane was the most promising. Seed treated with 2 ounces of actual lindane to 100 pounds of seed gave a nearly perfect stand, while adjacent untreated rows had a 10 to 20 per cent stand.

Mating behavior of *Perithemis tenera* Say and *Plathemis lydia* Drury (Odonata, Libellulidae) and its bearing on the theories of sexual selection. M. E. JACOBS, Indiana University.—*Plathemis* males occupy mating territories. Rivil males displace occupant males at intervals throughout the day. The white upper surface of the abdomen appears to be used to intimidate rivals. Artificially darkening of this surface depresses the territorial success and mating scores of the experimentals. Young males usually gain dominance which is progressively lost with age. Dominance is established by "marathon" racing. Males showing high mating scores during one period may show low mating scores during another, thereby demonstrating the importance of the entire case history in studies of sexual selection.

Perithemis males situate themselves near oviposition sites and appear to tire rivals by "dancing" and racing. An incoming female is pursued by a male after which she follows him to the oviposition site where male "courtship" occurs. A female seldom accepts a male until after she has been "courted" by several males at various territories. It is suggested that this behavior may allow the female an opportunity to select her oviposition site. A male with little or no mating success at one territory may be much more successful at another.

A preliminary report on insect tolerant alfalfa studies at Purdue University. M. CURTIS WILSON and RALPH L. DAVIS, Purdue University.—Studies underway at Purdue University show that there are significant differences in the susceptibility of different varieties of alfalfa to leafhoppers and spittlebugs. Some varieties appeared to be less attractive to these insects and consequently received lighter infestations and less injury in 1950 and 1951.

In 1950 spittlebug data were taken by visual observation using a rating system from 1-10 to determine spittlebug populations and also internode shortening caused by the insect. In 1951 square foot counts of spittlebugs showed a range from 57 spittlebugs per square foot for variety 87-C40 to 324 for variety 87-C42 with Ranger, 121; Grim, 152; and Buffalo, 159 intermediate. Data obtained by using the rating system in 1950 showed the same trend with 87-C40 rated a high 1.5 and Ranger 7.6 with 87-C42, 7.5. Buffalo appeared better in 1950 with a rating of 2.2.

Leafhopper data taken on the second crop of alfalfa showed a range of 116 leafhoppers per five sweeps for 87-C53 to 374 for Ranger with Grimm, 126; and Buffalo, 147. An average of three smaller samples taken in 1951 showed that 87-C53 continued to have a significantly lower number of leafhoppers than most other varieties.

Additional Notes On Indiana Bumble Bees (Bombidae, Hymenoptera)[1]

LELAND CHANDLER, Purdue University

In a previous paper by the author (1), fifteen species and three color varieties of Bombidae were listed as occurring within the state. Three of these species were listed without definite state records. Studies of additional material have resulted in definite records of two of these species, *Bombus ternarius* Say and *Psithyrus ashtoni* (Cresson), as well as one other species of *Bombus* and two color varieties of *Bombus* heretofore unrecorded. New locality records for a number of species already known to occur are also given.

Species and Color Variants New to Indiana

Bombus affinis var. *novae-angliae* Bequaert. This is a color variant of *B. affinis* Cresson and is known only from the worker and male castes. It differs from the typical species by the presence of some ferruginous pile on some of the abdominal tergites after the second. The Indiana specimen is a male and has the apical portion of the third abdominal tergite and the basal portion of the fourth abdominal tergite covered with ferruginous pile.

The specimen was collected by Prof. R. T. Everly of Purdue University in Miami County, two miles north of Peru. It was taken September 14, 1950 on aster. A typical male of *B. affinis* was taken on an adjacent goldenrod at the same time.

Bombus bimaculatus var. *ridingsii* Cresson. This color variant differs from the typical *B. bimaculatus* Cresson by the presence of yellow pile on some of the abdominal tergites after the second. The Indiana specimen is a male that has the fourth abdominal tergite entirely covered with yellow pile. It was taken on *Mentha* sp. by the author in Ripley County (Friendship) on July 11, 1951.

Bombus ternarius Say. A considerable amount of controversy has arisen in regard to the presence of this species within the state. Say, in his original description, noted "Inhabits Indiana". Franklin (2) doubted that it occurred in Indiana and Chandler (1) did not know of a record of its occurrence.

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[1] The author wishes to express his sincere appreciation to those persons who contributed specimens for this study; especially Mr. Charles Everly, Prof. R. T. Everly, Prof. G. E. Lehker, Dr. B. E. Montgomery, and Mr. Paul Roth.

Since this paper went to press a worker of *B. borealis* Kirby, taken by John Payne, a Purdue student, has been studied. This specimen was taken July 23, 1951 from the insect drift of Lake Michigan at Miller's Beach, Gary, Lake County. This is the first record of a worker of this species from Indiana.

During the 1951 Indiana State Fair, a 4-H insect collection belonging to Miss Florence Augustin of Newton County (Morocco) contained a worker of this species labeled "Newton County, Ind., 7-18-50, on flower". The specimen was removed, and arrangements are being made by Profs. G. E. Lehker and R. T. Everly to have the specimen deposited in the Purdue University collection.

Bombus terricola Kirby. A worker of this species, taken in St. Joseph County, was given to the author by Mr. Paul Roth, a student in forestry at Purdue. It was collected September 6, 1950.

The queens and workers of this species have the occiput black; the dorsum of the thorax yellow in front, the interalar region and scutellum black; pleurae black; the second and third abdominal tergites yellow; the remainder of the abdomen black, except for brown or light pile on the apical tergites. The males have some yellow pile on the face; thorax as in queens and workers; the second and third abdominal tergites yellow; the remaining abdominal tergites black, except for a considerable amount of light pile on the apical tergite.

Psithyrus ashtoni (Cresson). A male of this species was given the author by Mr. Paul Roth. It was collected on September 6, 1950 in St. Joseph County as was the worker of *B. terricola*. *P. ashtoni* is reported by Plath (4) to be an inquiline in the nests of *B. affinis* and *B. terricola*. Milliron (3) believes it to be most commonly inquilinous in the nests of *B. terricola* in Michigan.

New Locality Records of Bumble Bees Previously Reported from Indiana

Bombus affinis Cresson. Miami County

Bombus americanorum (Fabricius). DeKalb, Jefferson, Knox, Noble, St. Joseph, Scott Counties.

Bombus auricomus (Robertson). Clinton, DeKalb, Gibson, Howard, Jackson, Jefferson, Scott, White Counties.

Bombus bimaculatus Cresson. Jackson, St. Joseph Counties.

Bombus fervidus Kirby. DeKalb, Warren Counties.

Bombus fervidus var. *dorsalis* Cresson. Clinton, Fountain, Hendricks, Howard Counties.

Bombus fraternus (F. Smith). Fountain, Knox, Morgan Counties.

Bombus griseocollis (DeGeer). Carroll, Clinton, Jackson, Jefferson, Kosciusko, Scott Counties.

Bombus impatiens Cresson. Carroll, Clinton, Jackson, Jefferson, Miami, St. Joseph, Scott Counties.

Bombus vagans F. Smith. DeKalb, Miami, St. Joseph, Warren Counties.

Psithyrus laboriosus (Fabricius). Allen, Miami Counties.

Psithyrus laboriosus var. *citrinus* (F. Smith). Miami, Noble, Warren Counties.

Psithyrus variabilis (Cresson). Carroll, Ripley Counties.

No new state records of *Bombus borealis*, *Bombus perplexus*, or *Bombus vagans* var. *helanae* have come to the writer's attention. Neither has any definite record of the occurrence of *Psithyrus insularis* within the state been found.

A Note on a Melanic Queen.

While melanic specimens have been reported they are indeed rare. Franklin (2) reports seeing three such specimens, all queens, of *B. americanorum* and *B. auricomus*. The author has in his possession a melanic queen of *B. affinis* labeled "Tippecanoe County, April 16, 1925". As Franklin (2) states, the portion of the pile which is typically yellow is sooty and hard to differentiate from the black. Other than the abnormality of coloration, the specimen does not differ morphologically from normally colored specimens.

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The Japanese Beetle in Indiana

JAMES A. CLARK, State Entomologist's Office

The first Japanese beetle (*Popillia japonica*) reported in Indiana was found in Indianapolis in 1933. The following year, 1934, the Indiana Department of Conservation, Division of Entomology, in cooperation with the United States Department of Agriculture inaugurated a trapping program designed to locate and estimate range of the beetle. Seventeen beetles were found and thirty acres were treated with arsenate of lead to prevent establishment of the beetle in the area. In 1935 the trapping program was extended to other localities of Indiana where the Japanese beetle might possibly be introduced by transportation from New Jersey, New York and Pennsylvania, where infestations were established after introduction of the beetle in 1916. Fifty-nine beetles were taken in Indianapolis in adjacent area to the 1934 treated area, and fifty acres were treated. In 1936 beetles were found in Fort Wayne and South Bend; 1937 in Logansport; 1938 in Elkhart; 1939 in Bluffton, Muncie, Richmond, Warsaw and Whiting; 1940 in New Castle; 1941 in Hammond and Terre Haute; 1948 in Gary; 1950 in Jeffersonville.

A heavy infestation occurred in Richmond in 1942 when a total of five hundred and fifty-eight beetles were taken in traps. This localized infestation was treated and the following year only seventeen beetles were taken. This area was likewise treated and only four beetles were located. Following the treatment in that year no beetles were found by trapping. This example illustrates the fact that control methods are worth-while and effective when properly used to eliminate localized infestations. All beetles found prior to 1951 were localized, and controls used had prevented establishment of the Japanese beetle in Indiana (Table 1).

In 1951 an infestation was found at the southern city limits of South Bend. Over one thousand acres of suburban district is included in the area. Erskine Park Golf Course is the apparent center of the infestation and beetles were most numerous in the northwest corner of the course. One hundred eight-six acres of the most heavily infested area were treated with D.D.T. as a soil treatment. The area was also mist blown to kill as many adults as possible. During the flight period of 1952 an intensive mist-blowing program is planned to prevent as much spread as possible.

Arsenate of lead was used for soil treating until 1948; since that time D.D.T. has been used. D.D.T. has greatly reduced both cost and time needed to apply soil treatment. Both materials give four to five years residual deposit in average soils. To date one thousand seven hundred four acres have been sprayed to control the two thousand eight hundred forty-three beetles taken in traps.

Considering the reproductive potential and the number of beetles introduced into Indiana, this program has been very successful. It is

B.F.—Beetles found 2843
A.T.—Acres treated 1704

TABLE I. Japanese Beetle Data.

INDIANA	1934		1935		1936		1937		1938		1939		1940		1941		1942		1943		1944		1945		1946		1947		1948		1949		1950		1951	
	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT	BF	AT
Indianapolis	17	30	59	50	30	20	12	1	10	17	76	99	164	102	21	30	6		32	20	20	23	2		13	6	11	6	9	3	33	37	37	23	21	18
Ft. Wayne					5	25	18	16	20	18	105	22	52	16	5	9	4		8		96	71					2		7		19	12	240	86	214	81
South Bend					2		45	50	8	24			12	19															2				22	16	*	186
Logansport							1		9	15	98	38	13	10	5	1	9	6			7	4														
Elkhart									2		5		16	12	3	15	6		9		35	38	16	19	41	15	5	7	1		12	11	65	22	14	11
East Chicago									1																											
Bluffton											3																									
Muncie											1										1															
Richmond											1		7	13	4	13	558	19	17	33	4		1		2				9	6	1	4			1	
Warsaw											2		59	31	2																					
Whiting											21	17	4												1											
New Castle													2	4																						
Hammond															3	9	8		24	33	54	56	2		1				3	8	2				1	
Terre Haute															18	32									1								12	23	33	24
Gary																													6	7			1	3		
Jeffersonville																																	1		1	
Total	17	30	59	50	37	45	74	67	50	74	293	176	389	207	61	106	591	25	90	96	217	192	21	19	59	21	18	13	37	24	67	64	378	173	285	320

* Beetles numerous

a foregone conclusion that the yearly advance of the heavy infestation in the eastern states will some day cross our state boundaries. Until that time eradication of all known infestations will save the state many times the cost of control.

Insects of Indiana during 1951

J. J. Davis, Purdue University

In general, the 1951 season was unusually cool and unfavorable for the development of some of the major pests. Also during the winter of 1950-51 abnormal sub-zero weather occurred throughout the State, resulting in high winter mortality of some species.

Field Crop Insects

European corn borer (*Pyrausta nubilalis* Hbn.) did not have favorable weather for the development of the second generation in 1950 and therefore went into winter quarters with fewer numbers than usual. The winter mortality was probably higher than in normal winters because of the frequent sub-zero temperatures. Furthermore, the cool, wet spring of 1951 was unfavorable for development of the first brood. Even though conditions were somewhat more favorable for the second generation, the low population of the first generation did not permit the development of a high population. As a result little damage resulted in 1951 and the borers are going into hibernation this fall in comparatively few numbers.

Spittle bugs (Cercopidae) were unusually abundant and destructive, especially to legumes and strawberries. During the fall months of 1951 the adults have been conspicuous at lights and on various plants, but apparently the adults have done little or no damage to crops.

Wireworms (Elateridae) have become increasingly important throughout Indiana in recent years. Reports received during May, June, and July of the past year indicate the heaviest infestations and greatest losses for many years. These reports include damage to corn in the bottom lands of the Kankakee River area of northern Indiana, in the Wabash River valley area, and especially in the muck areas of northern Indiana, where they damaged not only corn, but onions, potatoes, and other crops.

The clover seed weevil *(Miccotrogus picirostris* F.*)* (Warner det.) was first found in Indiana by Poos and App, on red clover near Decatur, Indiana, in August 1951. This is the first authentic record of its occurrence in Indiana. The species has now been found in Oregon, California, Idaho, Minnesota, Wisconsin, Ohio, and Indiana. The first record of this insect in Ohio was obtained in June 1951.

Thrips *(Frankliniella tritici* Fitch*)* heavily infested small corn in southwest Indiana and threatened heavy damage to corn for hybrid seed. Favorable weather for corn and unfavorable conditions for thrips apparently was responsible for no appreciable damage.

Fall army worm *(Laphygma frugiperda* S. and A.*)* was quite damaging during September as far north as Greencastle.

The chinch bug (*Blissus leucopterus* Say) threatened the wheat and corn crops in northeastern and northwestern areas of Indiana. However, unfavorable weather prevented a general outbreak and damage was reported only from Lake County in northwestern Indiana, with a few threatening outbreaks in northeastern Indiana.

The Hession fly (*Phytophaga destructor* Say) is definitely on the increase in the southern half of the State although it caused no serious damage in 1951. However, unless farmers adhere to the fly-free sowing date, serious trouble may be anticipated.

The wheat jointworm (*Harmolita tritici* Fitch) is definitely on the increase and caused severe losses in the southern two thirds of the State. Along with jointworm increase there was an increase in the abundance and severity of the straw itch mite (*Pediculoides ventricosus* Newp.) as far north as Wabash and North Manchester.

Grasshoppers threatened as a pest this past summer but the outbreak did not materialize, probably because of weather which maintained succulent wild vegetation and prevented migration to cultivated crops.

The corn earworm (*Heliothus obsoleta* Fab.) was abundant and caused losses to maturing ears of corn in all parts of the State as observed during the corn borer survey during September and October.

The annual white grub (*Cyclocephala* sp.) was responsible for serious damage to turf in a number of regions in the northern half of the State.

The Japanese beetle (*Popillia japonica* Newm.) appeared in outbreak numbers in an area of some eight or ten square miles in southeastern South Bend. The State Entomologists Office in cooperation with the Federal Bureau of Entomology and Plant Quarantine are treating the area with soil insecticides in an effort to stamp out the outbreak.

The meadow plant bug (*Miris dolabratus* L.) was reported from several localities in central Indiana during June as attaching the developing heads of wheat.

Vegetable Garden Insects

Potato beetle larvae (*Leptinotarsa decemlineata* Say) were very abundant and destructive to field grown tomatoes in a number of areas during June. Observations in past years indicate injury to tomatoes, almost exclusively to field grown tomatoes.

The striped cucumber beetle (*Diabrotica vittata* Fab.) was a serious pest of melons and cucumbers in many areas but especially in the trucking region near Indianapolis. The adult beetles were also destructive to flowering plants during June in central Indiana.

Flea beetles (*Epitrix cucumeris* Harr.) were severe on newly set tomatoes in many parts of the State during May.

The bean leaf beetle (*Cerotoma trifurcata* Forst.) was reported abundant and destructive to early beans during May, in many parts

of Indiana. It was also feeding and causing damage to soybeans in Southern Indiana in September.

The Mexican bean beetle (*Epilachna varivestis* Muls.) was abundant in all parts of the State, probably because of the cool wet summer. In the Indianapolis area, damage was especially abundant to lima and pole beans.

The cabbage and radish maggot (*Hylemyia brassicae* Bouche) caused more damage than usual to cabbage and radish, especially early cabbage in the trucking reas of Indianapolis and northwestern Indiana. Turnips were also severely damaged in the fall.

Gordius round worms, parasites of grasshoppers and caterpillars, were frequently reported during the spring months in gardens following heavy rains.

Fruit Insects

The apple maggot (*Rhagoletis pomonella* Walsh) was abundant and destructive in the northern two tiers of counties.

The cherry fruit fly (*Rhagoletis cingulata* Loew) was abundant in several localities in northern Indiana. These are the first reports of serious damage for a number of years.

Red-banded leaf roller (*Argyrotaenia velutinana* Walk.) was abundant and destructive to apples in the fruit growing areas of southern Indiana this past fall.

The pear and cherry slug (*Eriocampoides limacina* Retz.) was frequently reported from most areas of the State.

The rose chafer (*Macrodactylus subspinosus* Fab.) was reported damaging many crops including apple fruits, rose and other flowering plants in the northern half of the State.

The strawberry sawfly (*Empria maculata* Nort.) defoliated strawberry plantings in several isolated localities during June.

Shade Tree Insects

Bagworms (*Thyridopteryx ephemeraeformis* Haw.) were very noticeably less abundant than in 1950, very likely due to the severity of the previous winter.

The cottony maple scale (*Pulvinaria vitis* L.) is on the increase in northern Indiana.

The European elm scale (*Gossyparia spuria* Mod.) and the elm scurfy scale (*Chionaspis americana* Johns.) are on the increase according to reports received from many parts of Indiana.

Pine leaf scale (*Chionaspis pinifoliae* Fitch) was frequently reported and is one of the commonest scales in the State.

The eight-spotted forester (*Alypia octomaculata* F.) has been unusually abundant the past year, defoliating Boston ivy in many places in the State.

Gall insects. During the past year many different plant galls have been sent in with reports of abundance. These include galls from oak,

hickory, willow, maple, elm, rose and linden. By far the most common one sent in was a mite gall on maple, known as the maple bladder gall (*Phyllocoptes quadripedes* Shim.). Although these gall formations may be abundant and disfigure foliage, they probably have little effect on the health and vigor of the hosts.

The hickory nut weevil (*Balaninus caryae* Horn) was observed to infest almost 100 per cent of shell bark hickory nuts although nuts of the shag bark hickory showed only a slight infestation.

The oak leaf skeletonizer (*Bucculatrix ainsliella* Murtf.) became noticeable in 1950 but in 1951 it was abundant and conspicuous throughout most of the southwestern quarter of the State browning the foliage of shingle or plane oaks.

Household and Structural Pests

The clover mite (*Bryobia praetiosa* Koch) was a common pest throughout the State during May, entering houses and causing annoyance.

Hackberry psyllids or jumping plant lice, emerging from galls on leaves and twigs of hackberry, have been unusually abundant this past fall, entering homes through screens and becoming annoying and getting into food.

Booklice *(Psocidae)* have been the subject of many inquiries throughout the State. This may be due to the fact that much building material now available is not kiln dried, which provides the damp conditions favorable for these annoying insects.

Termites (*Reticulitermes flavipes* Koll.) have been the subject of more than 150 specific inquiries during the past year. This is perhaps only a fraction of the requests for information because many inquiries were for publications only and not included in the above number of inquiries.

Powder post beetles *(Lyctidae)* have been reported as destructive from all parts of the State.

Ants are the source of many inquiries. In many cases the reports refer to annoying ants in the home, many refer to those disfiguring the lawn or occurring in the garden, but perhaps by far the majority of inquiries refer to swarming ants in the fall near foundations where they are mistaken for termites.

Stored Grain Insects

The problem of stored grain insects has been materially lessened, probably due to the sub-zero weather of the past winter. Similarly, the Angoumois grain moth (*Sitotroga cerealella* Oliv.) which has been such a serious problem for popcorn and hominy corn processors during the previous two years, was definitely checked and this also can be attributed to the sub-zero weather throughout the State during the past winter.

Appraisal of Residual Insecticide Activity Following Thermal Aerosol Application

JOHN V. OSMUN, Purdue University

The area application of insecticides by means of thermal aerosol generators, in an operation generally known as fogging, has attracted considerable public and commercial interest. Such applications are established as effective control for adult mosquitoes and black flies. Less is known about their effect on other insects, but regardless of the insect, the problem has generally been considered one of space control. Frequently, however, the question arises as to possible residual deposits from routine area fog applications. The observations reported here are the outgrowth of an evaluation of fogging as a means of housefly control and are reported here separately. The procedure was designed to appraise possible insecticidal activity of the deposits occurring on surfaces exposed to thermal aerosol application.

Little has been published on this subject although Collins (2) and Yeomans (7) reported convenient methods for measuring droplet size. Collins' technique, however was designed to evaluate results in indoors applications of fogs as reported by Collins and Glasgow (1). The attempt there was to control active clothes moths in a storage warehouse with little regard for active deposits. Osmun (5) exposed wool in closed buildings saturated with fog containing 20% DDT, and obtained significant deposits as indicated by protection tests using webbing clothes moth larvae. These tests have little bearing, however, on conditions occurring in area application.

Procedure

In the present tests, all applications were made with a commercial jet-engine type thermal generator modified to disperse measured amounts of insecticide. Each insecticide was formulated as a solution in an aromatic methylated naphthalene base oil. The exposure panels used were of two types: plywood and stiff glazed cardboard. Both types were cut into panels one square foot in size. Unless otherwise indicated, the panels were arranged as follows: at right angles to the fog stream, at 45°, edgewise vertically, and edgewise horizontally. In each case panels were arranged as indicated both on the ground and on wooden stands two feet above the ground (Figure 1). The usual placement of the exposure panels was 20 feet from the machine although closer applications were tested. The generator passed the panels at two mph.

On the particular generator used, a setting of #5 gave a dense fog which felt moderately moist three feet from the orifice. Droplet sizes at this setting ranged from 2-50 with the average normally

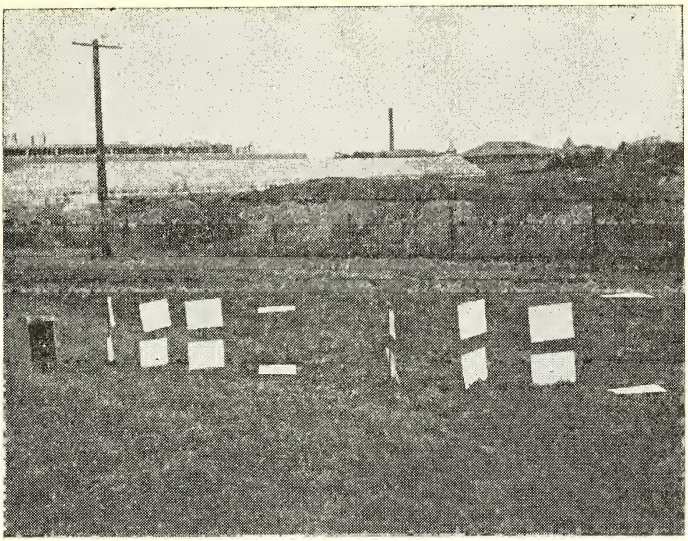

Fig. 1. Arrangement of exposure panels used to determine possible thermal aerosol deposits.

around 18. The insecticides were dispersed only on days when atmospheric conditions permitted the material to "smoke" the grass for 30 feet or more and completely blanket the panels as is shown in Figure 2. Wind velocity never exceeded three mph. It is sometimes a suggested practice in fog application to pass an exposure area twice in the same period of application. This is done to increase the opportunity for contact with insects which may have been sheltered or received only a sublethal dose the first time. In most of these exposures two runs were made, but one of two sets of panels was always removed between runs.

Four insecticides were used: chlordane in 1950, and again in 1951 along with DDT, lindane, and dieldrin. Percentage levels were held constant for each material to simplify the test and were set as follows: dieldrin and lindane 1.5%, chlordane 5% and DDT 10%.

Panel activity was bio-assayed 24 hours after exposure using standard 4-day old CSMA[1] house flies. Standards for comparison were set at 200 mg./sq. ft. for DDT, 100 mg./sq. ft. for chlordane, 30 mg./sq. ft. for lindane and dieldrin. Ten flies exposed for 30 minutes in eight ounce cardboard cages with screened tops and replicated four times on each panel. This exposure period was extended to 24 hours in certain instances, but all final readings were made at 24 or 48 hours.

Results and Discussion

In 1950 four separate exposures using chlordane were made with plywood panels placed 12 feet from the machine. The latter was not

[1] Chemical Specialties Manufacturers Association.

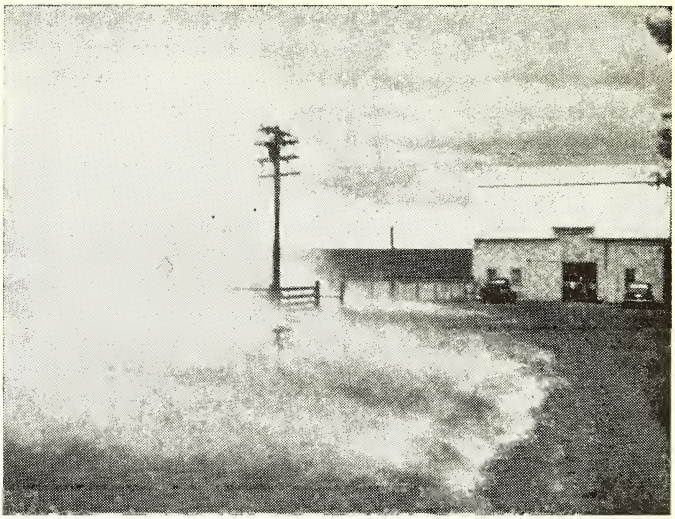

Fig. 2. Application of fog showing blanketing of exposure panels at left center.

moving but was allowed to disperse an insecticide for five seconds. No mortality was recorded on any panels in two exposures, 10% on one horizontal panel on the ground in the third exposurse, and 20% and 10% on horizontal panels on the ground and on the stand respectively in the fourth run. Although the untreated checks showed no mortality, it is doubtful that much significance can be placed on these low percentages in view of the stationary position of the generator.

In 1951 tests were numerous and varied in design to evaluate various aspects of the problem.

The results of one application using lindane at 20 feet are tabulated in Table I. No deposits of insecticide were detected by fly exposure even with 24-hour continuous exposure. All other 1.5% lindane tests gave like results. Similar exposures for chlordane, DDT, and dieldrin were conducted, and with the exception of the number moribund at the end of 30 minutes in the prepared standards, the results were the same, i.e., negative. In the case of the dieldrin panels, a total of 48 hours continuous exposure was made due to the generally slow action of this chemical. These results were also negative. No deposits were detected on the reverse side of several panels exposed facing the fog drift.

Since lindane in small quantities could conceivably lose its toxicity in 24 hours, one fly assay was made two hours after fog application. No mortality resulted.

The negative results obtained in these tests made it desirable to ascertain whether there had been a significant destruction of active principle in the thermal production of the aerosol, or whether it was

TABLE I. Adult Housefly Mortality on Panels exposed at 20 Feet to a Fog containing 1.5% Lindane

Panel position		30 min.[1]	24 hrs.	24 hr. total exposure[2]
One exposure:				
Ground perpendicular		0	0	0
Ground 45°		0	0	0
Ground 0° vertical		0	0	0
Ground 0° horizontal		0	0	0
2 feet up perpendicular		0	0	0
2 feet up 45°		0	0	0
2 feet up 0° vertical		0	0	0
2 feet up 0° horizontal		0	0	0
Two exposures:				
Ground perpendicular		0	0	0
Ground 45°		0	0	0
Ground 0° vertical		0	0	0
Ground 0° horizontal		0	0	0
2 feet up perpendicular		0	0	0
2 feet up 45°		0	0	0
2 feet up 0° vertical		0	0	0
2 feet up 0° horizontal		0	0	0
30 mg./sq. ft.	B	100% moribund	100% dead	——
Standard	A	100% moribund	100% dead	——
Check	A	0	0	0
	B	0	0	0

[1] Two replicates removed at end of this period.

[2] Two replicates exposed continuously for 24 hrs.

TABLE II. Adult Housefly Mortality on Cloth exposed to 1.5% Lindane at 1 Foot for 2 Seconds

	Alive	30 min.[1] % Moribund	Dead	Alive	2 hrs. % Moribund	Dead	Alive	24 hrs. % Moribund	Dead
Cage A.	10	90	0		22.5	77.5	0	0	100
Cage B.	0	100	0		30	70	0	0	100
Standard 30 mg./sq. ft.	0	100			17.5	82.5	0	0	100
Check	100	0	0	100	0	0	100	0	0

[1] Removal after this exposure interval.

TABLE III. Adult Housefly Mortality on Panels exposed at 4 Feet to Fog containing 1.5% Lindane

	Alive	30 minutes % Moribund	Dead	Alive	2 hours % Moribund	Dead	Alive	24 hours % Moribund	Dead
Test at 2 hrs.; 30 min. exposure									
Panel A	90	10	0	52.5	47.5	0	10	0	90
Panel B	82.5	17.5	0	50	50	0	30	10	60
Test at 24 hrs.; 30 min. exposure									
Panel A	100	0	0	100	0	0	22.5	0	77.5
Panel B	100	0	0	100	0	0	30	0	70
Test at 24 hrs.; 24 hr. exposure									
Panel A	100	0	0	100	0	0	0	0	100
Panel B	100	0	0	100	0	0	0	0	100
Check, unexposed	100	0	0	100	0	0	100	0	0
Standard, 30 mg./sq. ft.	0	100	0	0	30	70	0	0	100

simply a matter of distance with its related factors. A one square foot piece of cheese cloth was held 1 foot from the generator orifice dispensing 1.5% lindane for a period of two seconds. After drying 24 hours, the cloth was tested as indicated in Table II. Activity comparable with the standard was recorded. It should be noted however that cloth is a much better medium for deposit than the panels, and that the impinging pressure at that distance is considerable.

In another exposure to lindane, two panels were placed flat on the ground in direct line of fire at a distance of four feet. These panels received heavy, dark speckling from this exposure. The results, which are shown in Table III, indicate that significant deposits were made at this short distance, although they were less rapid in action after 24 hours.

One additional exposure was made in the routine fogging of a housing area with 5% chlordane. A porch 20 feet from the path of the generator was tested with flies in a manner similar to that used for the panels. The results were entirely negative.

There seems to be nothing unreasonable about the results when it is considered that the thermal aerosol is scattered in fine particles over a relatively large area. Even at 20 feet a given volume of fog has extended itself tremendously as compared with its compactness when leaving the four inch orifice. As Glasgow (3) pointed out, even to anticipate a DDT deposit of 200 mg./square foot would require the use of 17.5 pounds per acre. Yeomans (6) indicated that with the most ideal conditions, only about 50% of the insecticide can be accounted for and the loss becomes greater with abnormal climatic conditions. The work of Horsfall (4) shows that slight environmental changes are sufficient to cause irregular fog behavior, all of which decreases the opportunity for signifiicant deposit. Actually the little insecticide that is normally discharged by a fog machine is moving in the air in such small particles that most of them tend to pass around objects as part of the normal wind slip, and settle only gradually according to particle size. The positive results recorded on panels close to the generator are understandable in view of the compactness of the fog at such distances and velocity driving the aerosol against the surfaces.

The results of these observations should not be construed as indicating a lack of usefulness in thermal aerosol applications. Actually fogging is designed for immediate area space control of flying insects, and to that end no residual deposits are indicated. The test results do preclude the possibility of any lasting insecticide deposits over extensive areas following fogging applications.

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The Bagworm in Indiana

Donald L. Schuder, Purdue University

The bagworm, *Thrydopteryx ephemeraeformis* (Haw.), is one of the most important pests of ornamental trees and shrubs in Indiana. The evergreen species are most seriously affected but deciduous species are also subject to attack. The bagworm is a caterpillar which enclosed itself in a spindle-shaped cocoon-like bag covered with bits of leaves and foliage from the host plant. The caterpillar never leaves its protective bag but drags it along as the larva feeds. As it grows the bag is enlarged and it is almost impossible to pull the caterpillar from it.

Because of its importance, observations on the life history and control of the bagworm have been made during the past three years. Most of the newer organic insecticides have now been tested against this insect. Since this information will be of value to nurserymen, arborists, homeowners, park superintendents, foresters and greenskeepers it is being published at this time even though further work is planned.

Distribution and Host Plants

The bagworm is more common in southern and central Indiana than in the more northern portions, but in recent years has increased in abundance and in 1950 was reported as far north as Hammond. This insect has a long list of host plants but is particularly injurious to evergreens such as arbor vitae and junipers since they fail to recover from defoliation. The following is a partial list of the plants on which this insect has been observed in Indiana: arbor vitae, junipers, spruce, pine, larch, cypress, willow, maple, hazelnut, apple, hawthorn, poplar, cherry, pear, peach, quince, sycamore, linden, oak, elm, black locust, boxelder, horse chestnut, persimmon, Sassafras, sumac, dogwood, sweetgum, rose, barberry, and Clematis.

Life History

The bagworm has one generation per year and overwinters in the egg stage inside of the female spindle-shaped bag. At Lafayette these overwintering eggs hatch the last of May or the first of June. In 1949 the eggs began hatching June 4 in 1950 June 5, and in 1951 May 31. The bagworm caterpillar feeds ravenously until the middle of August or early September. Pupation of the male bagworms began on August 15 in 1949, on August 21 in 1950 and August 27 in 1951. At this time the bag is 1½ to 2 inches long and is securely webbed to a small branch of the tree. The clear-winged male moth emerges from the

pupal case inside the bag and mates with the wingless female which never leaves the bag. The male moths begin emerging as adults during September and continue to emerge during the warm days of October. In 1950 the first males emerged in outdoor cages on September 25. The peak of emergence occurred on October 24 and gradually declined until November 3. The weather then turned severely cold and no further emergence took place. The wingless larva-like female lays her eggs inside of the pupal case and the bag often contains several hundred eggs.

When dissecting the bags to make mortality counts for spray tests it was noted that there were two color forms of the larvae, some small and tan colored others large and purplish colored. The two forms were segregated and later checked for possible sex differences. The small tan larvae developed into males while all of the large purplish larvae developed into females. A similar study conducted in 1951 produced identical results.

Control

In the past the bagworm has been controlled by removing the bags and destroying them during the winter months, whenever the trees were small enough or the infestation light enough, to merit such a control measure. Lead arsenate has also been recommended for many years as an insecticide for controlling this insect, and if applied early in the summer while the larvae are small, is quite effective. However, as the larvae grow they become increasingly difficult to control with lead arsenate and the dosage must be greatly increased, and even then control is not always satisfactory. Unfortunately most people do not notice the bagworms injury until late July and August when the tree or shrub is nearly defoliated and the insect large enough to be difficult to control. Since there was a need for an effective insecticide that would control the bagworm late in the season, nearly all of the new organic insecticides have been tested during the past three years. DDT however was not tested as it was found ineffective by Bromley (1).

Methods

In late July and August when the bagworms were nearly mature infested shrubs in nurseries and private plantings in the vicinity of Lafayette were sprayed, using a Spartan sprayer, model No. 3, equipped with a tee jet nozzle and operating at 200 pounds pressure. The materials used were diluted according to the manufacturer's directions as shown in the following tables and applied until the foliage was thoroughly wet. One week after the application 25 or more bags from each treated tree were taken to the laboratory and opened to determine the per cent of mortality. Since diverse plantings had to be used for these tests, replication for statistical treatment of the data was not possible. The materials, dilutions and per cent mortality and date of application are shown in the following tables.

TABLE I. Results of Bagworm Spray Tests, 1949.

Material	Dilution per 100 gallons	Date of Application and Mortality					
	lbs.	Jul. 20 Pct.	Aug. 1 Pct.	Aug. 1 Pct.	Aug. 3 Pct.	Aug. 5 Pct.	Avg. Pct.
Parathion 25% wettable[1]	2				95.4		95.4
Parathion 25% wettable	1		96.0	84.2		100.	93.4
Parathion 25% wettable	½				93.8		93.8
Toxaphene 40% wettable[2]	4		100.0	86.6	90.3		92.3
Toxaphene 40% wettable	2	40.0			10.0		16.6
Penfluor 25% wettable[3]	1			15.8	46.0		20.6
CS 674A 50% wettable[4]	2			55.5	18.1		24.5
Chlordane 50% wettable[5]	2				4.0		4.0
B. H. C. 60% wettable[6]	2	25.0					25.0
CS 645 A 50% wettable[7]	1	12.5					12.5
Aldrin (118) 25% wettable[8]	1	0.0					0.0
Dieldrin (497) 25% wettable[9]	1	18.2					18.2
Lead Arsenate[10]	4		68	43.8			37.3
Untreated				.04	4.0		1.3

[1] O, o diethly O, paranitrophenyl thiophosphate, American Cyanamid Company.

[2] A chlorinated camphene having the empirical formula $C_{10}H_{10}Cl_8$, having 67 to 69 percent chlorine, Sherwin Williams Company.

[3] Fluorine analogue of DDT, Pennsylvania Salt Manufacturing Company

[4] 2-Nitro-1, 1-bis (p-chlorophenyl) butane, Commercial Solvent Corporation.

[5] 1, 2, 3, 4, 5, 6, 7, 8, 8-octochlora-4, 7-methano-3a, 4, 7, 7a tetrahydroindane, Dow Chemical Company.

[6] 1, 2, 3, 4, 5, 6,-hexachloro cyclohexane, Sherwin Williams Company.

[7] 2-Nitro-1, 1-bis (p-chlorophenyl) propane, Commercial Solvents Corporation.

[8] 1, 2, 3, 4, 10, 10-hexachloro-1, 4, 4a, 5, 8, 8a-hexahydro-1, 4, 5, 8 dimethano-naphthalene, Julius Hyman and Company.

[9] 1, 2, 3, 4, 10, 10-hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8a-octahydro-1, 4, 5,8-dimethanonaphthalene, Julius Hyman and Company.

[10] Standard lead arsenate, E. I. du Pont de Nemours and Company, Inc.

Results

Study of Table I reveals that parathion and toxaphene were the only materials which gave consistently good results, when applied late in the season when the caterpillars were nearly full grown and difficult to kill. These findings essentially affirm the findings of Bromley **(1, 2)** Stearns et al **(4)** and Polivka **(3)**. The remaining materials tested were relatively ineffective against the nearly full grown larvae.

In one case when compound CS 674A was used nearly all of the bagworms fell or crawled from the tree. Since the bagworms, even when killed, ordinarily remained webbed to the branch, this compound might be valuable if it would consistently give this repellent effect when used in conjunction with a more toxic insecticide. For this reason it was tried in combination with various insecticides in 1950 as shown in Table II.

From the results presented in Table II it appears that the synthetic organic prosphate compounds (Metacide, parathion, Systox and Potasan) are very effective against the nearly mature bagworms. The incorporation of CS 674A did not cause the bagworms to drop from the trees when mixed with toxaphene and parathion, but apparently gave the insecticides increased toxicity, possibly because of a synergistic action. The mortality from the application of toxaphene was relatively low but in previous experiments the mortality had been high. The low mortality may have been due to the use of an old sample of toxaphene. Compounds C-1014, EPN 300 and Aramite were less effective against the bagworm than lead arsenate.

The severe winter of 1950 reduced the bagworm population so there were not many specimens with which to work and a large number of experimental sprays could not be applied. Since two systemic materials, Systox and Potasan gave effective control in 1950, one gallon of diluted spray solution, (4 quarts per 100 gallons of water), of each was applied around roots of each infested pine tree in order to see if these materials killed bagworms by the systemic action. The applications to the soil were made on August 13 by hoeing a furrow around the base of each tree over the approximate feeding area of the roots. The possibility of a kill by fumigating action was ruled out since the larvae were all alive 24 hours after the application was made. Samples were taken 10 days after application, there was no bagworm mortality on the treated trees. It is apparent from these data that the systemic insecticides Potasan and Systox do not kill bagworms by systemic action when they are applied late in the season.

As a check on the possible fumigating action of some of the more effective insecticides 10 bagworms were wrapped in cheese cloth bags secured to the top of a cylindrical ice cream carton and a piece of filter paper moistened in spray strength solution of the insecticides, shown in Table III, was placed in the bottom of each carton. The test was set up August 23 and examinations were made 24 and 72 hours after the

TABLE II. Results of Bagworm Sprays Test, 1950.

Material	Dilution per 100 gallons	Date of application and mortality						
		July 6 Pct.	Aug. 2 Pct.	Aug. 7 Pct.	Aug. 9 Pct.	Aug. 17 Pct.	Sept. 15 Pct.	Avg. Pct.
Metacide 33% Emulsion[1]	¾ lb.				100.0			100.0
Parathion 15% wettable and	2 lb.					100.0		100.0
CS674A 50%	2 lb.							
Toxaphene 40% wettable and	4 lb.		99.0					99.0
CS 674A 50%	2 lb.							
Potasan 30.6% Emulsion[2]	1 qt.					89.0		89.0
Parathion 15% Wettable	2 lb.			88.0				88.0
Systox 32.1% Emulsion[3]	1 qt.					79.0		79.0
Lead Arsenate	4 lb.	44.0						44.0
Toxaphene 40% wettable[4]	4 lb.					30.0		30.0
EPN 300 30% Wettable[5]	1 lb.						20.0	20.0
C-1014 Emulsion[6]	4 qt.					4.0		4.0
Aramite 15% Wettable[7]	2 lb.					0.0		0.0
Untreated						0.0		0.0

[1] A mixture of parathion and the dimethyl analog of parathion, Pitts burgh Agricultural Chemical Company.

[2] Diethoxythio phosphoric acid ester of 7-hydroxy-4 methyl coumarin, Pittsburgh Agricultural Chemical Company.

[3] Trialkyl thiophosphate group, Pittsburgh Agricultural Chemical Company.

[4] The toxaphene used in this test was from a sample received in 1949, all other materials were from 1950 samples.

[5] Ethyl p-nitrophenyl thionobenzene phosphonate, E. I. du Pont de Nemours and Company, Inc.

[6] Octomethyl pyrophosphoramide, Dow Chemical Company.

[7] Beta-chloro-ethyl-beta (p-tertiary butyl phenoxy)-alpha-methyl ethyl sulfite. United States Rubber Company.

cartons were sealed with the average mortality shown in the following table.

TABLE III. Results of Fumigation Tests on the Bagworm 1951.

Materials	Dilution per 100 gallons lbs.	Average mortality 24 hours Pct.	72 hours Pct.
Toxaphene 40% wettable	4	6.6	16.6
Parathion 15% wettable	2	3.3	10.0
Metacide 33% Emulsion	¾	0.0	30.0
Lead Arsenate	4	0.0	5.6
Check-distilled water		0.0	10.0

On the basis of the data presented in Table III it would appear that the effective insecticides tested do not kill bagworms by a fumigating type action. Since these insecticides also possess contact and stomache toxicities, it is assumed that they kill by one or the other of these modes of action.

Summary

The bagworm is effectively controlled by toxaphene and the synthetic organic phosphate insecticides,—Metacide, parathion, Systox and Potasan,—even when the larvae are nearly mature and difficult to kill with lead arsenate. Systox and Patasan, although systemic insecticides, do not kill bagworm either by a systemic or fumigating mode of action when applied late in the season. Toxaphene, parathion and Metacide kill the bagworm by some other action than fumigating, probably by contact or stomache action since they possess these properties. All of the materials found to be effective against the bagworm, except toxaphene, are too toxic for the average layman to apply but nurserymen, arborists, park superintendents, landscape gardeners, and greenskeepers may use them effectively if the proper safety precautions are followed. Arsenate of lead is still an effective and safe material for bagworm control but must be used before the worms are half grown to be effective.

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GEOLOGY AND GEOGRAPHY

Chairman: C. L. Bieber, DePauw University

T. F. Barton, Indiana University, was elected chairman for 1952.

ABSTRACTS

Reclaiming coal mine spoils for agriculture. Helmut Kohnke, Purdue University.—Strip mining of coal has removed many an acre from agriculture. Reclamation efforts so far have been generally in the direction of reforestation. The majority of the coal land in the United States is in an area with a climate favorable for agriculture.

It must be welcomed therefore that research stations and coal operators alike are attempting to develop methods of reclaiming coal mine spoils for agriculture. It has been found that any plant species adapted to the vicinity can be established on the spoils except on the extremely acid ones. Grading spoils to an undulating topography permits the use of agricultural implements for seed bed preparation, fertilization, seeding and harvesting and widens greatly the land use capability. Hay and pasture crops have been established successfully on calcareous and on slightly acid spoils and have given generous returns.

Further research and experience is necessary to determine how many years in grass and legumes it will take for the rocks to decompose and soil structure to form before row crops can be grown. Whether it is economical to reclaim the more acid spoils for agriculture is problematic.

Circulation and settlement patterns of the Calumet Region of Northwest Indiana and Northeast Illinois (Third stage of occupance). Alfred H. Meyer, Valparaiso University, Valparaiso, Indiana.—This paper deals with the third of the four stages of occupance of the Calumet Region. The first and the second, dealing with the Pottawatomie and the Pioneer respectively, have been presented previously. The present is concerned with the geographic factors and forces instrumental in the development of the circulation and settlement patterns of the period from 1850 to 1900, noteworthy for the construction of roads and railroads, river and harbor improvements, development of commercial agriculture and urban communities, and the founding of basic industries for which the Calumet region is known throughout the world. Significant relationships of land and life are considered with reference to four primary geographic functions: geographic position, regional differentiation, interregional relationships, and recognizable areal correlations between the human and physical elements of the various environments.

The origin of the kinetic energy in the planets. JAMES A. REEVES.—This paper takes up the Tidal Theory of Jeans-Jeffrys on the origin of the solar system. It shows how the planets obtained their great kinetic energy of revolution and rotation.

The tongue of gas drawn out of our sun by a passing sun was caught between the two suns and given a mighty whirl by the gravitational pull of the two suns. The passing sun carried its side of the gas along after it, our sun carried its side in the opposite direction, the mutual gravitation of the gas particles in the tongue drew them together to form spheres. The outside layers of the spheres were given greater speed than the inner layers on account of their closer proximity to the two suns.

When these whirling spheres got beyond the heating power of the sun they cooled off and the heavier elements solidified.

Particles in bands far out from the axis of rotation of the sphere were revolving too fast to be drawn into the main sphere. They bunched up and became satellites.

The larger planets captured rings of gas from the other sun, which was traveling in the opposite direction, and formed retrograde satellites.

A proposed research project for southern Indiana. OTIS P. STARKEY, Indiana University.—Representatives from six Indiana University departments have drawn up a proposal to study the causes and effects of declining population in southern Indiana. It is hoped that by an intensive study of a relatively small area it may be possible to work out general principles of value in the analysis of areas with similar population problems elsewhere.

The Prediction of Alfalfa Yields in Southern Indiana from Soil and Plant Analyses

S. A. Barber, Purdue University

A series of experiments were conducted to determine the degree to which phosphate and potash levels in the soil control the yield of alfalfa. To do this it was necessary to attempt to produce yields which were only limited by factors other than plant nutrients so that they might be compared with yields where phosphate or potash was limiting. Soil and plant analyses were correlated with the degree of these phosphate and potash limitations on yield in order to attempt to obtain a procedure for prediction alfalfa yields on Southern Indiana soils.

The soil test procedure for predicting the response of alfalfa to potash additions was used by Chandler et al (2). From his experiments he was able to obtain a level below which a response might generally be expected. The use of plant analyses to predict fertilizer response has been investigated by Chandler et al (2), Bear (1), and Lundegaard (3). They obtained critical values for several nutrients above which a response to fertilizer application is not expected. These authors dealt mainly with critical levels and were not able from their experiments to predict the magnitude of response which might be obtained.

The plant nutrients which most seriously affect alfalfa growth in Southern Indiana are calcium, phosphate, potassium and boron. Any effects which might be due to insufficient calcium or boron were removed by supplying these elements in adequate amounts to all experimental plots. The limitation caused by the level of phosphate in the soil was determined by a comparison of the yield where adequate phosphate and potash were applied with that where adequate potash only was applied. Similarly the limitation caused by the soil potash level was determined by a comparison of the yield on the plot adequately fertilized with phosphate and potash with that fertilized with phosphate only. The yield on the phosphate-potash treatment was termed the maximum yield. The yields on the two other treatments were calculated as a percentage of the maximum yield. There were three treatments replicated three times. (Magnesium and boron treatments, not mentioned here, were also included in these experiments). These plots were located on twenty-six established alfalfa fields on farms of cooperating farmers across the southern part of the state. The various soils used included those that were derived from loessial deposits, Illinoian glacial deposits, residual limestone and river bottom sediments.

The fertilizer treatments were applied broadcast to the plots in March of 1950. Phosphate was applied at a rate of 200 pounds of P_2O_5 per acre, and potassium at a rate of 200 pounds of K_2O per acre. The soils were sampled before the fertilizer was applied. Three cuttings of hay were obtained from most of the plots and chemical determinations were made on the hay from the first cutting.

The soil samples were analyzed for available phosphate and potash by the procedures of the Purdue soil testing laboratory (4). This method consists of shaking 5 grams of soil with 15 ml of 0.75 NHCl solution for 2 minutes on a mechanical shaker. The extract is separated by filtration and an aliquot is used for determination of potassium by the flame photometer procedure. A second aliquot is analyzed for phosphorus by the colorimetric molybdic procedure. The plant samples were wet ashed by the nitric-sulfuric acid method. Phosphorus and potossium were determined on the solution by the same methods as those used for analysis of the soil extract.

The different locations used gave a wide distribution of both phosphate and potash levels in the soil. From this distribution it was possible to determine the limitation on yield as it was affected by the level of the nutrient in the soil. The results obtained from each location are expressed as a percentage of maximum yield so that all locations can be treated on a comparable basis.

The relation between the soil test for phosphate and the percent of maximum yield are shown in Figure 1. From this relationship we can

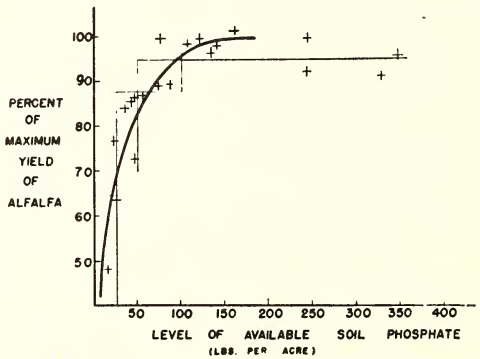

Fig. 1. The relationship between available soil phosphate and the percent of maximum yield of alfalfa hay.

predict that in order to get a mixiumum yield, the available soil phosphate level must be above 100 pounds P_2O_5 per acre. When it is between 50 and 100 pounds per acre we can expect a yield of between 88 and 95 percent of maximum. When it is between 25 and 30 pounds per acre we can expect a yield of 65 to 88 percent of maximum and when it is below 25 pounds per acre we cannot expect more than 65 percent of maximum yield.

A similar relationship between the soil test for potash and the percent of maximum yield obtained is shown in Figure 2. In order to obtain a maximum yield the potash level in the soil must be above 200 pounds per acre. When the level is between 150 and 200 pounds per acre we can expect a yield of 92.5 to 97.5 percent of maximum. With a level of 100 to 150 pounds per acre a yield of 80 to 92.5 percent of maximum could be expected.

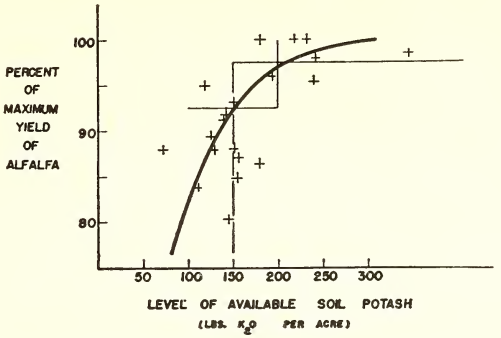

Fig. 2. The relationship between available soil potash and the percent of maximum yield of alfalfa hay.

There is a close relationship between the soil levels of available phosphate and potash and the production of alfalfa hay. From the levels found in any soil we can predict the limitation on yield caused by an insufficient supply of any one element and hence the need for fertilization. This experiment does not show the magnitude of interaction where both phosphate and potash are limiting.

The limitations of phosphate and potash on the production of alfalfa hay can be determined from the analysis of the hay for potassium and phosphorus. The relations between the percent phosphorus in the plant from the plots where no phosphate was applied and the percent of maximum yield obtained is shown in Figure 3. The phosphorus content of the hay from the plots where phosphate was applied is also shown. When the phosphorus content is above 0.3 percent we can not expect any appreciable increase due to phosphate application. The phosphorus content of the alfalfa from the plots believed to be adequately fertilized was between 0.3 and 0.4 percent. When the phosphorus content is between 0.2 and 0.3 percent we can expect a yield of only 80 to 95

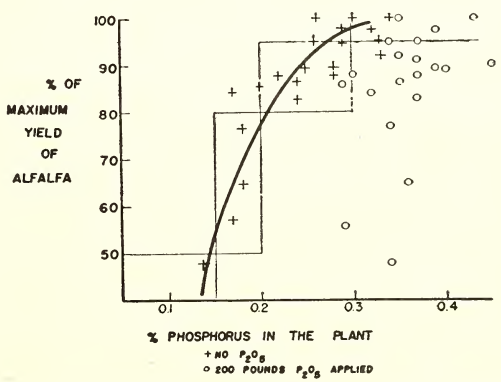

Fig. 3. The relationship of phosphorus content of alfalfa hay and the percent of maximum yield of alfalfa hay.

percent of the maximum yield. When the phosphorus level is between 0.15 and 0.2 percent we can expect a yield of 50 to 80 percent of maximum can be expected. When it is below 0.15 percent a yield of less than 50 percent can be expected.

Similarily, a relation between the level of potassium in the plant and the percent of maximum yield of alfalfa obtained is shown in Figure 4. Where the potassium content is above 2.0 percent the anticipated yield will be close to maximum. Where the content is 1.5 to 2.0 percent a yield of 90 to 95 percent of maximum may be expected. A potassium content below 1.5 percent will give an anticipated yield of less than 90 percent of maximum.

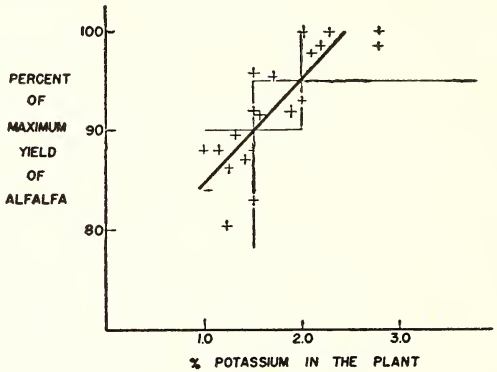

Fig. 4. The relationship of potassium content of alfalfa hay and the percent of maximum yield of alfalfa hay.

The values obtained here agree with those of Bear and Wallace (1). Their critical values for phosphorus in alfalfa is 0.27 percent and for potassium 2.0 percent. Chandler et al (2) obtained a figure of 1.25 percent for potassium below which a response of 20 percent or more could be expected.

These relationships show how it is possible to predict at what level an alfalfa field is producing either by testing the soil or the plant. This knowledge greatly facilitates the most economical use of fertilizer materials necessary to maximize crop yields.

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Population Growth of Indiana Cities, 1940-1950

Thomas Frank Barton, Indiana University

Introduction

The purpose of this paper is threefold, namely, (1) to present a brief statistical description of Indiana city growth during the past decade; (2) to give some tentative interpretations for the tempo of increase or decrease; and (3) to suggest a growth terminology with definite statistical meanings.

Statistics used in this study were secured from Preliminary Count: PC—2 and 3.

Exceptional Growth (Over 100 per cent increase)

Six cities in Indiana which more than doubled their population during the decade 1940-1950 are Charlestown, Clarksville, Griffith, Highland, Munster and Speedway. Charlestown's growth amounted to more than 400 per cent as it jumped from a population of 939 to 4,760. Munster shows a growth of over 170 per cent, an increase from 1,751 to 4,750. Of these six only Highland with a population of 2,723 was classified as a city in the 1940 census. During the past decade, Indiana passed a law qualifying a political unit with a population of 2,000 as a city.

In addition to their exceptional growth within this decade, these settlements have another characteristic in common, namely, they occupy rim locations to much larger cities. They all serve as residential settlements for persons commuting 15 miles or less to adjacent metropolitan areas. Should one draw circles with 15 mile radii around Gary and/or Hammond, Louisville, and Indianapolis, he will find that the circles enclose all six of these small cities. Only political boundaries separate Munster, Highland and Griffith from each other. And in turn, only a political boundary to the north along the Calumet River separates them from Hammond. They are only a few miles southwest of Gary.

Clarksville, sandwiched between the political boundaries of Jeffersonville on the east, and New Albany on the west, is just across the river from Louisville and forms a part of that city's metropolitan district. Charlestown is 15 miles northeast of Jeffersonville.

Only a political boundary separates Speedway from the western portion of Indianapolis.

In the 1950 census three cities are listed for which no population statistics were given ten years ago. They are Cedar Lake, Home Corner, and South LaPorte. Each has a population of over 2,500. The largest is Cedar Lake, with 3,945. It is less than 20 miles from the heart of either Gary or Hammond. South LaPorte is about equidistant from South Bend and Gary—a distance of less than 30 miles. Home

Corner is not shown on the most recent official state map of Indiana but is in Marion County adjacent to Indianapolis.

Excellent Growth (50-100 per cent growth)

Six of our cities show an excellent growth with increases from 50 to 100 per cent, namely, Angola, Columbus, East Gary, Lakeland, Walkerton and West Lafayette. Three of these are adjacent to or buttress larger cities. East Gary adjoins Gary. Walkerton is approximately 20 miles southwest of South Bend. Lakeland, adjoining Michigan City on the east, is about equidistant between Gary and South Bend.

The residential function also plays a part in interpreting the growth of West Lafayette since a new ruling was made for the 1950 census whereby part of the college students qualify as residents.

Columbus' growth is partially explained by the annexation of East Columbus, an unincorporated area with a population of about 3,500.

Angola in northeastern Indiana, 53 miles east of Elkhart, and approximately the same distance north of Fort Wayne, seems to be the only city in this group whose growth is not partially interpreted by employment opportunities in adjacent large cities, change in definition as to the counting of college students, or the annexation of adjacent residential areas.

Very Good Growth (25-49.99 per cent increase)

Seventeen Indiana cities show a very good growth during the past decade with increases between 25 and 49.99 per cent. The distribution of these cities again suggests the strong influence of relative locations adjacent to large city areas with work, shopping and service opportunities. Automobile transportation and hard-surfaced roads makes commuting twenty to thirty miles feasible.

Ten of these 17 cities are within a 25 mile radius of Indianapolis, Gary, Louisville and Cincinnati.

Four of them cluster around Indianapolis. Greenfield is 21 miles to the east, Danville is 20 miles to the west, Plainfield lies 8 miles to the southwest, and Beech Grove is only about a mile southeast of the Indianapolis boundary.

Four other cities from this group, Hobart, Chesterton, Crown Point and Valparaiso, are near Gary. The Hobart political boundary touches Gary on the west. Crown Point, to the south, Valparaiso to the southeast and Chesterton to the east are all less than 20 miles from Gary.

The last two cities of the ten, Jeffersonville and Greendale, owe their growth in part because they serve as residential areas for workers communting to and from Louisville and Cincinnati.

Of the seven remaining cities in this group of 17, the growth of three, and perhaps four, is partially or primarily explained by their residential function. Bloomington, as a university city, owes most of its increase to the ruling qualifying some college students as residents. Greencastle has and North Manchester may have benefitted by the same method.

Just east of Camp Atterbury, Edinburg partially owes its development to the influx of people during two wars.

Knox, Rensselaer, and Scottsburg, though not located near large cities or influenced by college student populations, show an increase of 25-49.99 per cent increase.

Steady Growth (10-24.99 per cent increase)

Forty-eight of the 138 cities in Indiana maintained a steady growth during the 1940's with increases of 10 to 24.99 per cent. (The reader should keep in mind constantly that settlements with 2,000 individuals qualify as cities according to state law.) These cities are well scattered over the state from New Albany in the southeast to Hammond in the northwest, from Evansville in the southwest to Fort Wayne and Kendallville in the northeast.

It is interesting to note that 14 of the state's 19 largest cities are in this group. Bloomington is the only one of Indiana's 19 largest cities which shows an increase of over 25 per cent.

Minor Growth (5 to 9.99 per cent increase)

Twenty-seven or approximately one-fifth of the cities reveal a minor growth from 5 to 9.99 per cent. Eleven of these are south of Indianapolis and 16 north. Indianapolis, our largest city, is in the list and so is Elkhart, the thirteenth largest city.

Practically No Growth (0-4.99 per cent increase)

Seventeen or over one-tenth of the cities showed practically no growth, and the group might be characterized as stagnant. They were simply able to hold their 1940 number and add a few families. Nine of these 17 are south of Indianapolis. Terre Haute, the seventh largest city in Indiana, had a growth of 2.2 per cent.

Minor Decline (0-4.99 per cent decrease)

Six cities, Aurora, East Chicago, Garrett, Mitchell, Petersburg and Princeton had fewer people in 1950 than ten years earlier. Garrett had only two people less and Mitchell had only a 3.5 per cent decline, but these cities failed "to hold" or retain their 1940 population figure. East Chicago is north of Indianapolis and the other five are to the south. The largest of these cities, East Chicago, is completely surrounded by other political units or Lake Michigan and cannot expand its territory materially. Consequently, as residential land gives way to other urban uses, East Chicago will probably continue to decline.

Serious Decline (Decrease of 5 per cent or more)

Eight cities showing a decline of 5 per cent or over are Bicknell, Bloomfield, Cannelton, Clinton, Jasonville, Linton, West Terre Haute and Whiting. Whiting, like East Chicago, cannot expand its political

boundaries and will probably continue to decline. However, the other seven cities in this group have ample space for expansion. It is important to note that four of these cities, Bicknell, Clinton, Jasonville, and Linton, are located in the coal fields of western Indiana, in areas where extensive strip mines have been or are in operation. Bloomfield is on the edge of the Crawford Upland, the most rugged and least desirable physiographic region in southern Indiana from the standpoint of cultivated agriculture.

Urban Growth Terminology

Would it not be wise for us to adopt a descriptive word terminology so some definite statistical limits are borne in mind when we say a minor growth, or steady growth or excellent growth?

In preparing this study, the following table of descriptive terms and their statistical values seemed appropriate:

Descriptive Term	*Statistical Value*	*No. of Cities in Indiana, 1940-1950*
Exceptional Growth	100 per cent and over	9
Excellent Growth	50-100 per cent	6
Very Good Growth	25-49.99 per cent	17
Steady Growth	10-24.99 per cent	48
Minor Growth	5-9.99 per cent	27
Practically No Growth	0-4.99 per cent	17
Minor Decline	4.99-0 per cent	6
Serious Decline	5 per cent or more	8
	Total	138

The third column indicates the number of cities to which the term is applied.

Summary

Indiana's 19 largest cities in 1950 failed to grow rapidly during the past decade. Only Bloomington had an increase of over 25 per cent.

Forty-eight cities or approximately one-third maintained a steady growth.

Thirty-two or about one-sixth show a very good to exceptional growth. Nine of these more than doubled their population. Twenty-four of the 32 have benefitted substantially by a favorable relative location, namely, a short commuting distance to the largest Indiana cities or to the metropolitan districts of Louisville and Cincinnati. The growth of four additional cities is partially interpreted by qualifying college students as residents.

It becomes obvious that the residential function has played an important role in providing a stimulus for development in these rapidly

growing cities during the past decade. It may be that the feasibility of commuting has decentralized factory workers during the past ten years more rapidly than companies have decentralized their factories.

As we look to the future more of these small cities with their important residential function may become a part of expanding urban area or metropolitan districts.

Cities with the greatest decline are concentrated in southwestern Indiana especially in the coal fields.

Tolleston and Post-Tolleston Beaches and Bars in Lake County, Indiana

C. L. Bieber, DePauw University

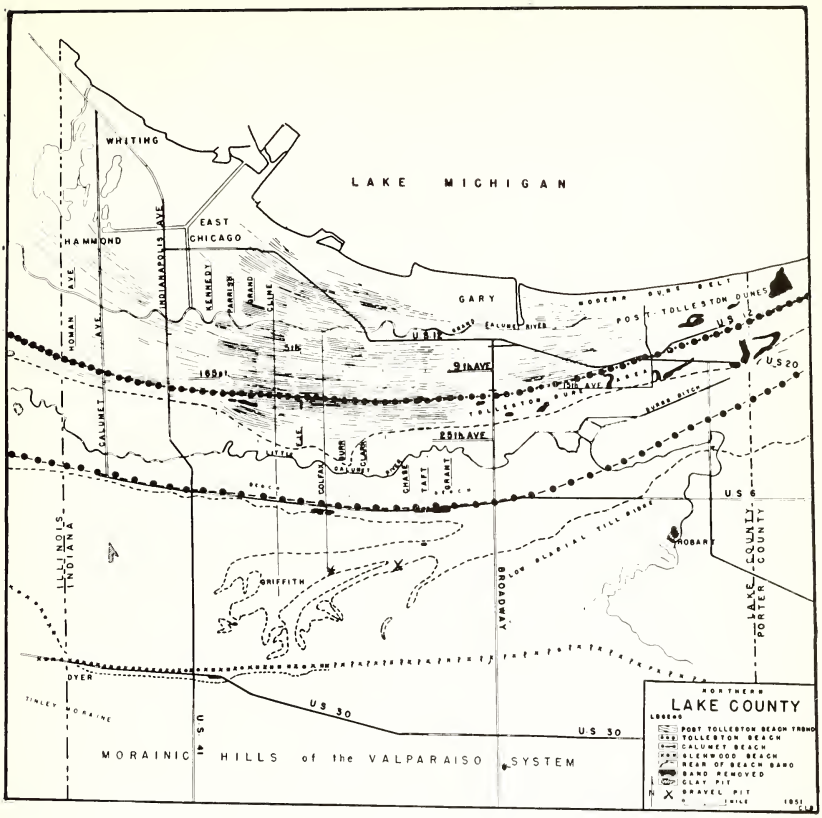
The history of glacial Lake Chicago has been set forth, modified, and reviewed by various authors. The purpose of this paper is to describe and interpret beach and bar deposits of Tolleston and post-Tolleston age in Lake County.[1]

Late in Pleistocene history, stabilization of levels of Lake Chicago at about 20 feet above present lake levels formed a beach line that passes one-half mile south of Tolleston, an early settlement near Tenth Avenue and Garfield Street in Gary. The Tolleston beach, where not obscured by dunes, is represented by a series of sand ridges parallel to the lake shore at the time of deposition. The lake must have stood near the 600 foot level for a long period, as these sand ridges stand about 20 feet higher than the surrounding plain. This type of beach development is in strong contrast to the Calumet beach, which lies to the south and consists of a single main ridge except for the embayment in the Griffith area.

In late Tolleston time the Straits of Makinac cleared of ice and allowed drainage to the east, probably through the Port Huron outlet, which is in glacial till. The lake levels gradually lowered as the outlet eroded forming low parallel beachlines and bars on the level plain in northern Lake County. Earth movements in post-Pleistocene time along with temporary halts in the erosion of the outlet, have complicated the problem of interpreting the history by a study of the ancient shore lines. However, in the main, the evidence shows a slow and steady withdrawal of the water level in post-Tolleston time. Some of the details of the pattern of Tolleston and post-Tolleston beaches and bars are hereinafter set forth.

The Colfax Street embayment—The north-south extent of the Tolleston beach sand ranges between a third of a mile and half a mile. However, between Parrish Avenue and Clark Street in sections 13 and 14, T. 36 N., R. 9 W., the sand area extends southward in a broad arc for 1½ miles from the high beaches. (Pl. II, fig. 1). In this area, which lies south of the main Tolleston beach deposits, low sand ridges probably represent bars or temporary halts in a shallow embayment before the deposition of the main beach sands. The embayment may be a remnant of the sag which formed the bars and spits in the Griffith area during the Calumet stage of Lake Chicago. (Pl. I, fig. 1, 2) Though these ridges are meager and of subdued expression, they present evidence of a gradual retreat from the Calumet to the Tolleston stage. If the ancient Calumet River acted as a sluice over the newly formed

[1] Published with permission of the State Geologist, Geological Survey, Indiana Department of Conservation.



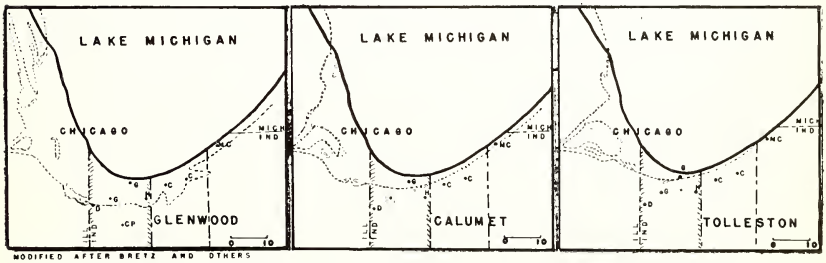


Plate I. Maps of Lake Chicago beaches and bars.

Fig. 1. Map of northern Lake County showing trends of Tolleston and post-Tolleston beaches and bars.

Fig. 2. Beaches of Lake Chicago, represented by dotted lines.

Plate II. Aerial photographs of beach and bar detail.

Fig. 1. Sand ridges showing embayment features in the Colfax Street area.

Fig. 2. Post-Tolleston beaches and bars in the west limits of Gary.

lake plain, the river may have destroyed other ridges of a similar nature. The embayment extends 3 miles east-west and 1 mile north-south.

Ridged nature of the Tolleston beach deposits—In the western half of Lake County from near Grant Street in sections 8 and 17, T. 36 N., R. 8 W., the beach sands lie in ridges that parallel the ancient shore. (Pl. II, fig. 1) These ridges may represent foredunes along the former lake shore. The lake levels did not hold long enough to heap sufficient sand on shore to be modified greatly by wind. Moreover longshore currents transported quantities of the sand eastward toward Porter County.

Seven distinct parallel sand ridges comprise the major part of the beach deposits in the vicinity of Colfax Street and Eighteenth Avenue in the west part of Gary. The north-south distance across the ridged sand is approximately one fourth mile and the highest part of the complex of ridges is 17 feet above the plain to the north. The depth of the sand beneath the beach varies from 25 to 40 feet (2). The marshy flats to the south of the main complex are approximately 6 feet above the flats on the north side of the Tolleston sands.

Westward near the Illinois line the ridges are distinct but are only about 10 feet above the marsh land. The ridged Tolleston beach deposits of west Lake County are here interpreted to indicate a very slight gradual lowering of the lake level during the Tolleston stage.

Eastern Tolleston beach deposits—In sections 9, 10, 11, and 12, T. 36 N., R. 8 W., from Grant Street eastward, in an area of more abundant sand, the straight parallel ridges gradually give way to winding ridges, knolls, and connecting banks of sand. These transitional features between Grant and Georgia Streets in Gary are now mostly destroyed by the growth of the city. From Georgia Street eastward to the Porter County line dunes nearly 50 feet high are developed. Several of the highest of the dunes are being removed by commercial sand companies.

Even though Tolleston waters withdrew slowly, sufficient sand gathered in eastern Lake County so that active dunes developed on the shore sands. Shapes of the dunes indicate strong winds from the northwest, which blew the sand landward. Even more persistent southwest winds transformed the elongate dunes into barchane shapes. Here, even amongst the confusion of dunes, a pattern of rather prominent sand ridges closely parallels the main Tolleston beach line. The ridges are probably modified ancient foredunes.

Post-Tolleston beaches and bars—The Tolleston levels finally dropped more rapidly due to stoppage of the Chicago outlet by bedrock and increased erosion of the Port Huron outlet. Thus the old bars and beaches were abandoned as the lake shore retreated. However, small fluctuations in levels truncated the Tolleston beach dunes of the Aetna-Miller areas in the eastern section of Gary before definite retreat of the shore waters took place. Excellent examples of such dunes are east of Miller near the Porter County line along U. S. Highway 12.

From the Tolleston ridges and dunes northward to the present lake shore low sand ridges alternating with linear swampy areas are the most conspicuous features of the lake plain. (Pl. II, fig. 2) Remainders of 70 such ridges may be counted along Whitcomb Street, 78 along the Elgin, Joliet, and Eastern Railroad, and 68 in the vicinity of Clark Street. Industry along the lake shore and ever-expanding subdivisions have destroyed many of these features. Northward along Colfax Avenue, from the Tolleston beach to the present lake shore, the average width of ridge and swamp together is near 250 feet. Locally ridges may be crowded or scattered.

Near the Illinois line along Detroit Street a typical ridge measures 4½ feet high and 70 feet wide. The inter-swamp area south of the ridge is 70 feet wide. In the SW¼ sec. 4, T. 36 N., R. 9 W., along 165th Street in Hammond, several ridges average 6 feet above the swamp level. They measure 90 feet from crest to crest while the swampy areas between average 50 feet across. In the SE¼ sec. 33, T. 37 N., R. 9 W., along Michigan Street, the height of the ridges above the swamp is 6 feet, the width 40 feet, and the width of the swamp 50 feet. Along Chicago Avenue in Gary in the SW¼ sec. 26, T. 37 N., R. 9 W. the sand ridges average but 2 feet in height and 100 feet from crest to crest. Along Clark Street in Gary in the SE¼ sec. 25, T. 37 N., R. 9 W. the ridges are from 5½ to 7 feet above the swamps. Width of the ridges average 40 feet and the swampy areas between average 45 feet.

The beach and bar lines are essentially parallel to one another and nearly parallel to the present lake shore. However in the East Chicago-Whiting district where the extreme flats of the former outlet exist, the ridges are farther apart. On the other hand, east of Broadway Street in Gary and north of Fifteenth Avenue the ridges converge because of the narrower and more steeply graded lake plain.

Increase in quantity of sand toward the lake head has built up higher ridges in the central and east part of the county. These crowded higher ridges have condensed the sand area so that wind work has confused the pattern and produced sizeable dunes. Eastward from Gary Municipal Beach in the Miller district prominent dunes are formed, some of which take crescent shapes. Many of these dunes are large enough for commercial exploitation.

Evidence for Nipissing and Algoma beaches—One and one-fourth miles north of the northernmost Tolleston ridge in the vicinity of the E.J.E.R.R. in the NW¼ sec. 2, T. 36 N., R. 9 W. is a series of sand ridges slightly more prominent than the adjacent ones, although not as high nor as conspicuous as the Tolleston sand ridges. (Pl. II, fig. 2) They probably represent a slowing in the erosion of the northeast lake outlets, or perhaps slight uplifts of the land to the north. These ridges may correlate with the Nipissing stage, whose beaches are prominent farther north in Michigan **(4).**

The Grand Calumet River has located its valley where the beach bars are lower and more closely spaced. One mile north of the Grand Calumet River along Clark Street another set of more prominent ridges

is located in the NE¼ sec. 36, T. 37 N., R. 9 W. These may correlate with the Algoma beaches of Michigan. Northeast of Gary in sections 32 and 33, T. 37 N., R. 7 W where these two sets of ridges merge on the narrowed lake plain, wind has blown the beach sands into high dunes.

Generally, however, evidence for halts in the regression of the lake level is meager. The sand ridges indicate a slowly retreating lake shore which has continued since Tolleston time right down to the past few hundred years. Evidence is lacking for any major readvance of the lake levels after the final retreat from the Tolleston levels began. Present recorded levels of Lake Michigan show fluctuation of little more than 3 feet in the past 75 years.

Age of the sands—Recent studies by the radiocarbon method have dated wood found between glacial drift sheets in Wisconsin (3). The relationship of the beaches to the drift sheets (1) indicates that the Tolleston beach sand may be 5000 to 7000 years old. If this estimate is fairly accurate, the post-Tolleston sand ridges of probable Nipissing age south of the Grand Calumet River may be from 3000 to 5000 years old, and those northward from the river are less than 3000 years old becoming increasingly younger toward the lake shore. If major readvances of the lake have not occurred since Tolleston time, and 7000 years have elapsed while the water receded from the Tolleston beach to the present shore, the lake water along Clark Street in Gary has receded an average of about 2.4 feet per year since Tolleston time. On the whole, the sand ridges where undisturbed by man appear to have been deposited very recently. The ridges are covered with vegetation, but the sand is little affected by weathering.

Conclusions—Sand ridges that show on aerial photographs in northern Lake County represent a slowly receding lake shore in post-Tolleston time. The ridged complexity of the Tolleston beach sand indicates a retreating shore, even at the time the main beach sands were accumulating. An embayment may account for the sand accumulation in the Colfax Street area near 25th Avenue. As interpreted from radiocarbon studies, the Tolleston beach sand is from 5000 to 7000 years old. Little evidence for Nipissing and Algoman beaches exists, although some series of ridges are more prominent than others.

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Soil Conditions after 60 Years in a Purdue Pasture Lot

T. M. Bushnell, Purdue University

The new Life Science building at Purdue is being constructed in a 4 acre blue grass lot which had been heavily pastured for over 60 years. Before basement excavations were begun, some soil samples were taken and tested to check whether or not the land-use had affected the ground Little modification was expected because data at hand indicated little change below plow-depth in other land, which had received heavy applications of limestone or fertilizers.

When the data from the first samples showed surprisingly great and deep accumulations of "available" P_2O_5 and K_2O additional samples were taken to check and fill in the picture. In October, 1950 additional samples were taken from the undisturbed profiles along the basement excavations. When construction proceeded the chance for further sampling and study was lost forever.

The soil of the pasture was Warsaw silt loam—a grassland type with a dark brown silt loam, A horizon about 10" or 12" deep; brown to reddish-brown silty clay loam to clay loam, moderately acid, main B horizon; with a darker, neutral, gravelly clay loam zone above the abrupt contact with dry, coarse, calcareous gravels at a depth of 3 or 4'. The mat of blue grass roots was 2 to 4 inches deep.

The land sloped gently towards the southwestern corner, as shown by contours on Figure 1. Rainfall readily penetrated the porous soil and substratum and there was no waterlogging even when there was some run-off to the depression south of the border of this lot.

For many years, up to 45 or 50 dairy cows grazed this area from late April or early May to about June 15 or 30. The lush early grass gave way to patchy growth where cattle avoided droppings. The close cropped sod was dormant during the drier summer, but fall growth was pastured again from about September 1 or October 15 to December 1. Sheep were also on that lot at various times. Stock grazed the whole area but often congregated at the corners. The southwest corner near the gate and water trough was most heavily trampled, covered with droppings and short on grass.

In addition to natural droppings the whole area received top dressings of about 5 tons of manure per acre in the spring for 7 years or more. About 300# per acre of 3-12-12 fertilizer was applied for 5 years. No one knows how much more may have been added in other years.

Warsaw silt loam normally tests about as shown in Figure 2. It is estimated that the profile to a depth of 3 feet contains about 300 pounds of available K_2O and 400 pounds of available P_2O_5.

When it was found that the "available" P_2O_5 and K_2O were about normal in the soil samples taken from the 3 corners of the lot farthest

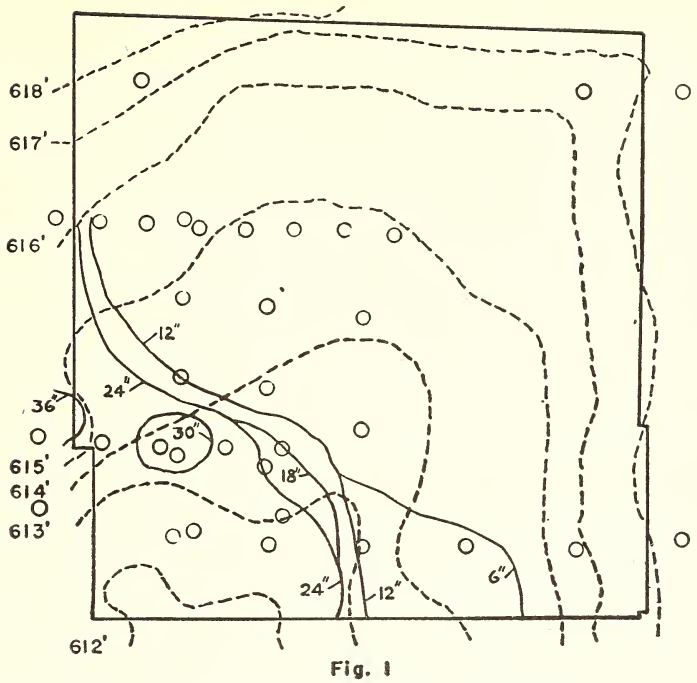

Fig. 1. Outline of Purdue Dairy pasture lot showing elevations by dotted lines, sample locations by small circles and depths of very high K_2O tests by solid lines.

from the gate, samples were taken from the land just outside the pasture for comparison. Altogether the data show little if any increase in available P_2O_5 and K_2O in those corners which are about 400 feet from the lot gate. Using these data as a basis for comparison, it is evident that large accumulations of available P_2O_5 and K_2O have occurred in the southwestern portion.

The highest readings given by the testing methods are 294# P_2O_5 and 400# K_2O. In many cases the soil samples evidently contained much more than those amounts. In Figure 1 there are lines indicating about where these maximum tests for K_2O occurred, and the depths to which they extended. It is obvious that great accumulations of fertility in top soils were found about 300 feet from the southwest corner, and enrichment continued thru concentric zones towards the gate to increasingly greater depths. High tests for K_2O extended down to over 3 feet in some spots. High tests for P_2O_5 were located about the same as for high K_2O in the 6″ layer, and high P_2O_5 extended to 12″ in about the same locations where high K_2O reached depths of 24″.

Available information will not permit quantitative or sure conclusions about the conditions described in this paper but some inferences seem fairly reasonable.

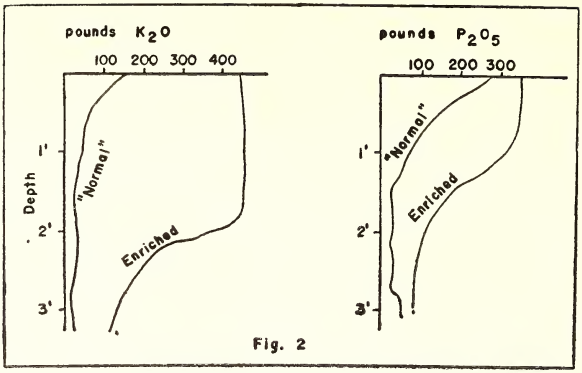

Fig. 2. Amounts of K_2O and P_2O_5 in "normal" Warsaw silt loam according to tests in distant corners of pasture lot, and in the "enriched" soil of the southwestern corner near the gate.

There was little if any change in the appearance of the soils or in the reaction profiles within this field. The blue-grass sod seemed rather mediocre considering the fertility it received. There was little indication of soil change related to land use and management in the corners distant from the gate.

The amounts of fertility nearer the gate ranged up to concentrations of about 2100# available K_2O per acre in 3 feet, or about 7 times as much as the 300# in 3 feet of "normal" Warsaw silt loam. Similarly the available P_2O_5 was over 1000# or about 2½ times the 400# in 3 feet of "normal" profile.

The penetration of K_2O was greater and deeper than that of P_2O_5 which is in line with recognized principles of soil chemistry.

The estimated accumulation of K_2O is about double of that of the P_2O_5. This fact is in harmony with the relative proportions of K_2O and P_2O_5 in manure, although it cannot be assumed that composition of manure is the cause of the correspondence.

It is uncertain why the local concentration of fertility is so pronounced. It is estimated that the density of animals per unit of area and time might easily have been 10 times as great in the southwestern corner as in other corners of the lot. That alone might be enough to account for having from 3 to 7 times the "normal" amount of fertility. On the other hand, the slope of the lot from the 3 distant corners toward the lower area near the gate probably helped to increase the fertility contrast by washing something from the 3 corners and adding it to the one low corner. However the 1 foot contours of slope and the lines of relative fertility concentrations differ enough to weaken the correlation between those two factors.

The amount of K_2O and P_2O_5 added to this land during 50 years or more may be roughly estimated at 10,000 and 5,000 pounds respectively. The amounts removed in 50 years of pasturing might be 3,000

and 500 pounds of K_2O and P_2O_5 respectively. This all goes to show there are many things unaccounted for by the available information and points to data needed for a complete study. The tests *do* show greater accumulation of fertility than the writer has ever seen reported elsewhere.

The Growth of Strip Coal Mining in Indiana

Robert D. Loring, DePauw University

This paper will trace and attempt to account for the growth of the strip coal mining industry in Indiana from the year 1914 up to, and including, the year 1949. The year 1914 is significant nationally with respect to this industry as it marked the first time that one million tons of coal were mined by strip operations in the nation. The year 1949 is chosen as the latest year as it is the last year for which comparable national and state-wide data on coal production is available.

While strip mining had been known in Indiana since 1904, the industry did not achieve major significance until 1917. In 1914 when the nation reached the one million ton level for the first time, Indiana produced slightly more than 170,000 tons by strip methods. In three short years, however, Indiana had achieved the one million ton level for the first time. Since 1917 Indiana dropped below this level only twice.

Since 1904 strip mining operations have taken place in some fifteen counties of the state. In 1949 fourteen counties were actively engaged in strip coal mining—Clay, Daviess, Fountain, Gibson, Greene, Knox, Owen, Parke, Pike, Spencer, Sullivan, Vermillion, Vigo, and Warrick (2). These same counties were also active in strip mining in 1948, which will be used as a more typical year for comparison purposes than 1949. The year 1949 is totally atypical due to the great drop in the total coal production in Indiana that year mainly as a result of the effect of the three day work week then prevalent in the coal industry. This drop was a reversal of the general upward trend in that industry prior to that year. The fact that 1949 was atypical is further evidenced by the upturn in coal production in Indiana since that year, an upturn that is in keeping with the trends evident before 1949.

The growth of strip coal production in Indiana from 1914 to 1948 has been slightly more than double the growth of the entire coal industry in the state. The net increase in the total coal production by all methods from 1914 to 1948 was 5,914,916 tons; whereas, the increase of coal produced by strip or open-cut methods during the same period was 13,385,719 tons.

The total amount of coal produced by all mining methods in Indiana has fluctuated widely in the twenty-six year period between 1914 and 1949. There were twelve years in which the 1914 production figure of 16,641,132 tons was not equaled—1928, 1930, 1931, 1932, 1933, 1934, 1935, 1936, 1937, 1938, 1939, and 1949. With the exceptions of 1928 and 1949 the low production figures represent the overall depressed state of industry in general during the immediate post-depression period. These years primarily represent the 1930 to 1939 period. Since then, and with the exception of 1949, the coal production has risen to a point where, by 1940, it had maintained itself at a production level in excess of 20,000,000 tons per year.

During the same period, 1914-1949, there were fourteen years during which the preceding year's level of production was not reached. These years were 1919, 1921, 1922, 1924, 1927, 1928, 1930, 1931, 1932, 1938, 1945, 1946, 1948, and 1949. The year of peak coal production in Indiana was 1918 when 30,310,102 tons were produced (1). The lowest production ebb came in the immediate post-depression years with only 12,557,029 tons being produced in 1932.

Percentage-wise, a greater proportion of Indiana coal has been produced by strip mining methods than for a comparable basis on the national level. From 1914 to 1949 the percentage of bituminous coal produced by open-cut mining methods by the nation as a whole rose from 0.33% to 24.2%; whereas, for the same period the figures for Indiana show a percentage increase from 1.02% to 58.81%. Indiana's peak year was 1948 when 59.23% of her coal was produced by strip mining methods.

Between 1914 and 1949 the tonnage of coal produced by open-cut methods in Indiana multiplied over fifty-four times. We should remember that 1949 was an abnormally low year due to strike conditions. If 1948 is taken as the nearest normal year, we find that the tonnage of coal produced by strip methods in 1948 was almost seventy-nine times greater than that produced in 1914. The production of bituminous coal by strip methods reached the million ton level for Indiana in 1917. Only in 1919 and 1921 did the production fall below the million ton mark. The increase in strip coal production has been a fairly steady one. In no year did the production fall below the 1914 level and in only eleven years—1919, 1921, 1930, 1931, 1933, 1938, 1943, 1945, 1946, 1948, 1949—did it fail to reach that of the preceding years. The peak production year was 1942 when 13, 807,067 tons were produced by open-cut methods.

The largest single tonnage increase in strip coal production was between 1940 and 1941 when an increase of almost 3,000,000 tons was reported. The production during and following the war years remained high with more than 11,720,000 tons being produced each year until 1949. In 1949 the production dropped to a point below that of 1939 with but 9,293,956 tons being produced, as a result of the three day work week. Despite the drop in production strip mining still managed to maintain its importance with respect to the general coal industry of Indiana as the general coal industry was also depressed. In 1949 Indiana produced 58.81% of her coal by strip methods. This represented a percentage decrease of less than 0.5% from the preceding year.

With respect to production there have been two periods of reasonably steady strip coal production, one from 1929 through 1934 when about five million tons were produced and the other from 1940 to 1946 when the production was in the neighborhood of twelve to thirteen million tons.

Probably the main reason for the expansion of strip coal mining is the fact that the coal can be produced more cheaply by this method than underground methods. There are perhaps six reasons that would account for this cheapness of production: (1) there is little coal wastage as no coal has to be left to support the mine roof; (2) more machinery

can be used, thus enabling a greater overall production; (3) smaller labor costs per ton due to the large number of machines; (4) there is a savings on insurance rates as a strip mine receives the same rates as does a regular construction company; (5) the cost of mine ventilation is eliminated; (6) the cost of hoisting the coal to the surface is largely reduced.

The importance of strip coal mining to Indiana can best be shown by the state's ranking as a coal producer and strip coal producer. In 1948 Indiana ranked sixth as a coal producer and fifth as a strip coal producer in the United States. Of the leading coal producing states Indiana produced a greater percentage of her coal by strip methods than any other state.

Summary

Strip mining has been known in Indiana since 1904; however, it was not until 1917 that one million tons of coal were produced by this method of mining. Since then the production of coal by open-cut methods has grown from slightly less than 5% of the total coal produced in 1917 to 58.81% in 1949 with the high point being 59.23% in 1948. In large part it is the low cost and ease of operation which accounts for the increase of production by this method.

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The Swallow-holes of Lost River, Orange County, Indiana[1]

Clyde A. Malott, Indiana University

Abstract

Lost River of southern Indiana has an upper area of surface drainage on an upland limestone plain, a middle area of subterranean drainage through a perched sinkhole plain, and a lower area of intrenched drainage at or near baselevel. Intrenchment of the lower section of Lost River permitted the lowering of the watertable of the middle area and sinkhole topography and sinking drainage followed. The upper area of surface drainage on the limestone upland remote from the intrenched lower part of the stream basin remains unaffected and still has a watertable limited by the stream itself. The sinkholes, the sinking streams, the lengthened and little used dry-bed section of Lost River, and the capacious cavernous underground drainage routes of the middle section have been developed during the present cycle of drainage intrenchment, and they are the products of invading surface waters keeping pace with a progressively lowered or withdrawn watertable in the perched section of the limestone upland.

Foreword and Acknowledgments

The field work upon which this paper on Lost River is based was begun in the early 1920's and has continued intermittently through a period exceeding 25 years. The later years of the study have consisted chiefly in observations on the stormwater behavior of this most interesting drainage system in Indiana. In the early work the dry-bed channel was planetabled and at least 135 square miles of the drainage basin were mapped by contours based on carefully checked aneroid barometer determinations of altitudes and closely spaced traverses. The altitudes given in the present paper are relatively correct and are presented without apology. The descriptive material deals mainly with the drainage characteristics and topographic features of some 160 square miles of the upper Lost River basin which characterizes a section of the Southern Indiana Karst. It is the most complete and accurate report ever made on Lost River, and the writer hopes that it will prove useful to others interested in subterranean drainage studies and the characteristics of a fairly large stream which has sought underground routes through cavernous conduits many miles in length. It should be especially helpful in indicating the location and characteristics of the leading features associated with Lost River as a subterranean stream system. The efficiency of the surface waters to develop cavern-

[1] This paper is published posthumously as a memorial to the author, expenses of publication being met largely by Dr. Malott's family by special arrangement with the Academy.—Ed.

ous routes and caverns themselves is inescapably manifested in a region which runs rife with cavernous routes, and the conditions under which caverns originated and the machinery which developed them in a limestone region are given considerable attention.

Grateful acknowledgment is made to the Waterman Foundation of Indiana University for subsistence and expense funds during the summers of 1926 and 1929; also to the Department of Geology, Indiana University, for funds to defray expenses for shorter periods of study and trips made to the Lost River region over a period of years. Further, grateful acknowledgment is made to Robert R. Shrock, now of Massachusetts Institute of Technology, for help in the mapping of some 30 caverns and holes in the Lost River region during the summer of 1929. Only 3 important caverns of those explored and mapped have been described and their details published. One other is mapped and described in the present paper.

Lost River Drainage System

The entire Lost River drainage system occupies approximately 355 square miles in portions of Washington, Orange, Lawrence and Martin counties in southern Indiana. The system extends mainly westward for an airline distance of 33 miles, draining a broad area in two diverse physiographic terrains. Its upper section is largely on the Mitchell plain, an upland of slight relief underlaid by the Middle Mississippian limestones, dipping gently westward, and characterized in part by sinkholes, sinkhole topography and sinking minor streams. Much of the headwater section and the trunk stream of Lost River to near Orangeville are on the St. Louis limestone, though most of the dismembered sinking streams and much of the sinkhole plain are developed on the superadjacent Ste. Genevieve limestone. Only minor intermittent streams descending sharply from sandstone ridges pass over the still higher Chester formations. The lower section of the drainage system is in the rugged Crawford upland west of the Mitchell plain, where the relief is much greater, and where the terrain is characterized by deep valleys and rugged standstone ridges developed on the Upper Mississippian (Chester) and Lower Pennsylvanian (Mansfield) sandstones. The eastern border of the Crawford upland of southern Indiana is formed by the much eroded and irregular Chester escarpment which rises 100 to 200 feet above the Mitchell plain adjacent to it. The irregular Chester escarpment has been pushed westward where it is crossed by Lost River, but it swings abruptly eastward along the southern edge of the upper part of the basin for a distance of 15 miles or more (Fig. 1). The sprawling drainage of Lick Creek, an important tributary entering the lower section of Lost River near West Baden, lies south of the eastward extending escarpment and wholly within the Crawford upland area. A considerable section of the lower course of Lost River is on the Ste. Genevieve limestone which forms the floor of the valley in the eastern part of the highly dissected upland. Farther west in Martin County the stream in turn passes over the various Chester formations

of the Upper Mississippian and terminates on the massive Mansfield sandstone of the Lower Pennsylvanian.

Lost River and its tributaries originally formed a normal dendritic system throughout its area, but a considerable part of its upper section has been disrupted by the development of subterranean drainage and many of its former tributaries have been diverted from their former surface courses. At least 160 square miles of the drainage system in whole or in part have succumbed to subterranean drainage, and in large areas a sinkhole plain has been developed with little or no evidence of the former tributary courses (Fig. 1). The rainfall on such areas

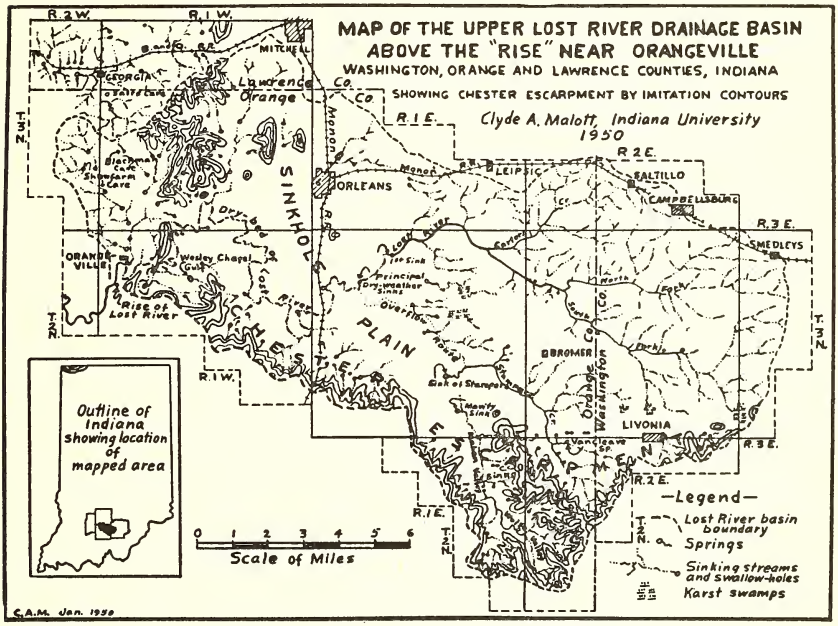

Fig. 1. The drainage basin of Lost River above the resurgence of the underground stream near Orangeville comprises an area of 160 square miles. Some 47 square miles of the drainage in the headwater region is normal surface drainage which sinks in swallow-holes into an underground system and re-appears more than 7 miles west of the first sinks. The sinkhole plain in the middle of the mapped area contains thousands of sinkholes, and all former tributaries have been dismembered from the dry-bed course of Lost River. Stampers Creek is the largest of these dismembered streams, but its system is also greatly broken up by sinking drainage diverted from it. Its perennial head is at several springs which get some of their supply from waters diverted underground from the South Fork of Lost River near Livonia. In the rugged upland back of the Chester escarpment underground drainage is developed in karst valleys, the surface drainage descending from the sandstone-capped ridges. The drainage of an undetermined area of many square miles along the B. and O. Railway in Lawrence County has been diverted underground southward into Lost River, the waters re-appearing at the Orangeville "rise". A portion of this diverted drainage is shown on the map.

almost immediately becomes subterranean. Some areas, however, discharge their drainage waters through normal surface courses from upland areas, but become swallowed up on reaching the lower sinkhole plain. These surface stream courses are the upper parts of former streams which reached the trunk stream of Lost River, but now are the distal and dismembered branches ending in swallow-holes. This drainage condition is especially prevalent where the drainage descends from the sandstone-capped hills of the Chester escarpment or comes from the areas within the Crawford upland along the south side of the drainage basin and in the region west of Orleans and north of Orangeville.

Stormwaters in several small intermittent former tributaries sink in successive swallow-holes in the upper parts of their shallow valleys and along their former courses now within the sinkhole plain. "Old Sulphur", heading some 3 miles east of Orleans, and Pearson Creek, heading near Mitchell, are two examples. Stampers Creek, along with the partially karsted floors of Mahan and Wolfe valleys, formerly composed an area of approximately 40 square miles which drained into Lost River, but now is diverted underground southward and westward to the deeply intrenched Lick Creek where the waters return to the surface as springs and resurgences. In very exceptional rainfalls Stampers Creek floods a large area about its terminal swallow-hole and excess waters follow a former surface route for 4 miles across the sinkhole plain and enter the trunk stream of Lost River a short distance below the main dry-weather sinks of that stream. This nearly lost course is scarcely discernible in normal times and roads cross it without bridges. At one place a cemetery partly occupies it and a church is dangerously nearby. The Stampers Creek system itself has been greatly disrupted and dismembered through subterranean diversion, so that now scarcely 15 square miles of drainage discharge into its terminal swallow-hole (Fig. 1).

Lost River itself heads on the broad divide south of Smedleys at an altitude of 900 feet, and with its various branches occupies a broad, gentle westerly sloping area between Campbellsburg and Livonia in Washington County (Fig. 1). Its two forks join one mile west of the county line in Orange County where the main stream has descended to an altitude of about 685 feet in a distance of a little more than 6 miles. Two miles farther west it is joined by Carters Creek which is a normal surface stream. The relief of the upland limestone plain in the headwater region is slight, but in the localities of the junction of the two forks and Carters Creek the main stream occupies a broad, open valley 60 to 80 feet below the upland surface. The headwater region with its many branches in Washington County is essentially without sinkhole development and its small branches carry waters intermittently in the manner of normal headwater branches. Near the county line several small springs appear along the two forks of Lost River and others enter below the junction of the two forks in Orange County. The waters of these springs are clear and their flows do not fluctuate greatly. All of them are situated close to the streams which their

waters enter. Their aggregate flow is sufficient to keep water running in the main stream west of the Washington county line. The largest spring noted is the Johnson spring in the NW¼ of sec. 7, T. 2 N., R. 2 E., 1¾ miles west of the Washington county line. Its average flow is estimated to be about 75,000 gallons per day. These springs represent the terminals of small initial subterranean systems which originate upon the limestone upland nearby. They are incipient underground systems so small that they have not yet affected the topography and are bedrock seepage routes wholly above the streams into which their terminals discharge. They are gravity springs fed by percolating waters draining from the rock and do not have any significant amounts of waters from sinkholes or sinking streams entering their systems.

Below the junction of Carters Creek only a few rather small stormwater tributaries enter Lost River, and shallow sinkholes make their appearance on the upland. Here the upland surface has descended to an altitude of 700 feet. Three miles below Carters Creek, Lost River has reached westward well into the sinkhole plain, and the first sink appears in the stream channel, and with it the perennial stream ends. Here the stream has descended to an altitude of 625 feet, and the sinkhole plain adjacent to it is only 650 to 675 feet in altitude. The sinkhole drainage of the upland is complete, beginning at or near the 700-foot contour line. Few surface streams survive on the upland below 675 feet in altitude. The drainage absorbed in the sinkholes no longer reaches the surface stream; instead, it goes below into the same subterranean system that has sapped the waters of the main stream. It is here, also, that the intermittent dry-bed channel of Lost River begins.

The dry-bed channel of Lost River is a well developed channel which passes westward across the sinkhole plain in a tortuous course at least 22½ miles in length to the large resurgence or rise at Orangeville. This distance is three times the direct distance of 7½ miles (Fig. 2). The channel is 12 to 16 feet in depth, and in the first 11 miles of its course its rather gently sloping banks are largely composed of soil normally covered with grass or other vegetation. Trees are commonly present on all parts of the banks and locally in the bed of the channel itself. The outer banks are rather far apart, in many places exceeding 100 feet. The channel bed is locally quite narrow, but in places it is 50 feet or more in width. Islands are not uncommon. Locally both the gently sloping banks and the bottom form rich pastures of grass, and occasionally crops are planted across the entire channel and it becomes a part of the cultivated fields through which it passes. The downstream gradient of the upper 11 miles of the course is rather gentle, averaging only about 4 feet per mile. The remaining 11 miles or so of the dry-bed course has a gradient of nearly 8 feet per mile. This section has a wider flooor, and a rough, rocky bottom prevails. Its banks are locally steeper and in many places composed of exposed rock. The complete descent of the dry-bed between the first sink and the Orangeville resurgence or rise is 130 feet,

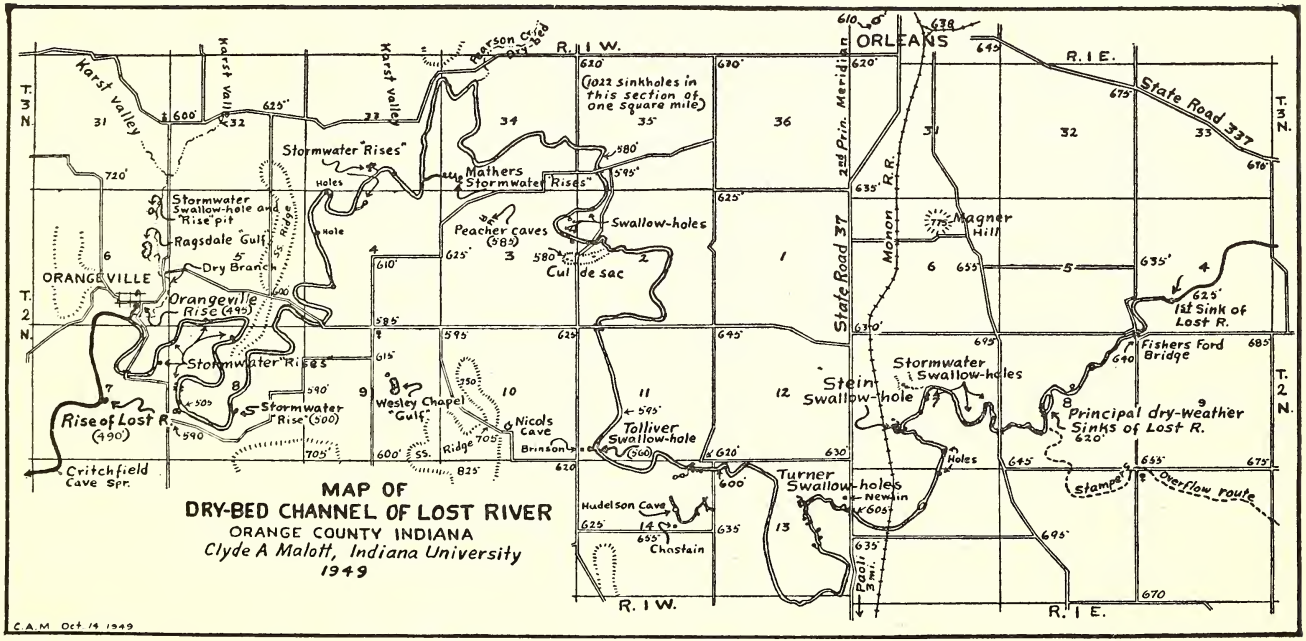

Fig. 2. The tortuous dry-bed channel of Lost River across the sinkhole plain is 22½ miles in length. The map shows both the locations of its known swallow-holes in the upper perched section of the dry-bed and the stormwater resurgences in the intrenched lower section reaching to the terminal and perennial "rise" of underground Lost River south of Orangeville. Underground Lost River is a complex, multi-channel course which passes westerly beneath the surface from the principal dry-weather sinks to the perennial "rise". The underground system may be entered at the Tolliver swallow-hole and at the Wesley Chapel "gulf". The dry-bed course is a stormwater channel only. Its middle portion is used only following very heavy rains. Its upper and lower sections are used more frequently. Figures indicate altitudes along and adjacent to the dry-bed channel.

the latter having an altitude of 495 feet. In the first 10 or 12 miles below the first sink in the channel the dry-bed is but little below the sinkhole plain itself, but it becomes deeply intrenched before reaching the Orangeville resurgence. The lower part of the dry-bed channel and the resurgences near Orangeville are in the rugged Crawford upland where sandstones cap the ridges between the deeply set limestone valleys. Below Orangeville the remaining 30 miles or so of Lost River to East White River is a winding, deeply intrenched stream with a rather low gradient at the baselevel of the region.

Topographic expression and physiographic development

Physiographically all of the Lost River drainage system is in the driftless area of southern Indiana, and the upland surface is a part of the widely extensive Tertiary peneplain characterizing much of the upland area south of the glacial boundary in the central interior region of the United States. This widely developed upland peneplain is characterized by two or more topographic levels, and is therefore compound or multiple in topographic expression. One topographic level is at an altitude of 900 feet or more, and the other is developed below it at an altitude of about 750 feet, though local areas have been reduced below the latter level. The 750-foot level adjacent to the main streams in southern Indiana is characterized by local areas of upland gravels generally assigned to the Lafayette formation of late Pliocene age. The altitudes and topographic expressions of the upland areas are dependent upon the lithologic characteristics of the rocks underlying different sections of the terrain, upon former baselevel controls, and upon nearness to important drainage lines. The compound upland plain locally has been greatly modified by erosive reduction and stream intrenchment below the upland levels. A considerable part of the sinkhole plain of the Lost River region has been greatly reduced by solution of the limestone under its soil cover and only limited areas are preserved at the 750-foot level.

Lost River heads upon the higher and remnantal surface of the Tertiary peneplain at an altitude of 900 feet. This surface is preserved only on divides in southern Indiana. Much of the drainage reaching from the 900-foot topographic level and descending to the 750-foot level is surface drainage in the limestone terrain. It does not become subterranean, however, until it reaches still lower altitudes. The sinkhole plain proper is developed in the Lost River region almost entirely below an altitude of 700 feet, and down to 600 feet along the western edge where it abuts against the irregular Chester escarpment. The altitudes at which sinkholes are developed, however, are greatly dependent upon nearness to or distance from intrenched drainage, or upon only slightly lower drainage areas in a down-dip direction of the underlying limestone strata. Some sinkhole areas are developed at 800 feet in altitude or even slightly more, such as the local sinkhole development in the locality of Livonia between some of the branches of the South Fork of Lost River and headwater resurgences of Stampers

Creek on the west. The latest developed Tertiary partial cycle, typically represented at an altitude of 750 feet, undoubtedly had some subterranean drainage of its own, but much or all of it is lost, or so overshadowed by the lower and later developed sinkhole plain and its underground drainage that little is left which may be assigned to it. It is possible that some of the sinking drainage descending from the Chester escarpment along the south side of the upper Lost River basin may have been inherited from the latest Tertiary partial cycle.

The Chester escarpment marks the irregular eastern edge of the Crawford upland and ascends to an altitude of 900 feet or more. The escarpment is capped by clastic rocks (principally sandstones of Upper Mississippian or Chester age). In its easterly swing a short distance east of Orangeville it forms the entire southern margin of the upper Lost River drainage basin, and the stormwaters of scores of sharply descending intermittent streams become separately subterranean at or near the foot (Fig. 1). Although the upper surface of the Crawford upland stands 150 to 200 feet above the karsted limestone terrain, it is deeply trenched and eroded through valley development. Many of its main valleys are cut to much lower levels than the upland limestone plain and reach through the clastic rocks into the same limestone sequence. Lost River itself passes westward into the rugged upland in a deeply cut valley and reaches an altitude of less than 500 feet at Orangeville. The subterranean waters of Lost River and the sinkhole plain return to the surface within this rugged region, and many of the smaller valleys of the eastern section of the upland have karsted limestone floors with local and individual subterranean drainage. The large and well known resurgence or rise at the village of Orangeville is the terminus of the underground drainage of a series of karst valleys to the north, and possibly also from considerable areas of the sinkhole plain itself, and its entrance into Lost River terminates the dry-bed channel. This resurgence is not the rise of Lost River. It is, however, an important tributary of that stream.

The present underground drainage of Lost River, the cavernous routes, the detached former surface tributaries, and the thousands of sinkholes of the extensive sinkhole plain are all products of the present geomorphic cycle and are post-Tertiary in development. They are features developed on an upland surface that is considerably below the level of the latest Tertiary partial cycle. The regional uplift which closed the latest Tertiary partial erosion cycle marked the beginning of the present valley intrenchment and the dissection and reduction of the partial peneplain. Lost River cut the lower part of its valley deeply below the partial peneplain, eventually leaving the upper part of the meandering course of the stream perched upon the limestone plain 200 feet or more above its deeply intrenched section downstream from near Orangeville. The present meandering course of the dry-bed was inherited from the preceding cycle.

The intrenchment of Lost River in the Orangeville region and the effective rejuvenation of the upland limestone plain upstream was not suddenly accomplished. Only slight entrenchment, however, permitted

some development of underground drainage and the watertable to be drawn down, thus initiating the present cycle. The western section of the perched limestone plain was affected much earlier than areas farther east and more remote from the intrenched section of Lost River. As a consequence of the nearness of the western section of the upland plain to the intrenched section of Lost River, the lowering of the upland surface began in an early stage of the present cycle, while the more remote and eastern part of the upland plain and of Lost River itself were little affected, even as they are today. The western section of the limestone upland has been greatly lowered, both by surface erosion and solutional reduction, and much of it is below 700 feet in altitude and the westernmost areas are 600 feet or even less. Also the perched limestone upland adjacent to Lost River has been pushed farther west by the stripping away of the Chester sandstones and shales, and the exposed limestone there has become well karsted at much lower altitudes than the largely destroyed Tertiary partial peneplain.

The development of underground drainage and the lowering of the watertable in the karsted area of the Mitchell plain was progressive from west to east. In the earlier stages relatively shallow underground drainage passages were made and are now either eroded away or are represented by the present higher cavern levels, some of which are quite dry. Sinkhole development and the loss of surface drainage to underground routes were more or less restricted to the western margin of the limestone upland. Lost River probably sought underground routes in which only limited parts of the present dry-bed were involved in partial disuse. It is quite possible than an early sink was developed in the SW¼ of sec. 8, T. 2 N., R. 1 W., about 1 mile southeast of Orangeville, with the sinking waters returning at the present resurgence or rise on the Allen farm three-fourths of a mile south of Orangeville (see Fig. 2 for locations.) Another sink was developed in the NE¼ of sec. 3, T. 2 N., R. 1 W., about 2½ miles southwest of Orleans, with its underground route leading through the decadent Peacher cave system and to the present stormwater resurgence in the steep-head on the Mathers farm in the SW of SW¼ of sec. 34, T. 3 N., R. 1 W. Still later Lost River sank farther up stream at the Tolliver swallow-hole in the SW of SW¼ of sec. 11, T. 2 N., R. 1 W., and its waters developed the present underground route through the Shirley or Wesley Chapel gulf and thence on to the present resurgence on the Allen farm. In the meantime the lowering of the watertable on the perched limestone plain allowed regional solution to take place in the well-bedded and well-jointed limestones and the sinkhole topography became quite extensive, enveloping large areas. Still later Lost River probably began sinking at the Turner swallow-holes in the NE¼ of sec. 13, T. 2 N., R. 1 W. In turn the Stein swallow-hole, in the SW¼ of sec. 7, T. 2 N., R. 1 E., was developed, and eventually sinks were developed upstream to the present main dry-weather sinks in the NE of SW¼ of sec. 8. The last sink to form in the stream is still farther upstream in the SW¼ of sec. 7. It appears to mark the very initiation of a sink which

in time may become well developed. Concomitant with the progressive development of sinks farther and farther up stream and the lengthening of the dry-bed channel, regional sinkhole development and detachment of former surface tributaries took place, producing the extensive sinkhole plain and the sinking streams which characterize the region today.

The Sink of Lost River

Lost River sinks in its channel because of the development of underground channels in the upper portion of the St. Louis limestone slightly below the level of the stream channel. The subterranean channels are the product of subsurface solution by waters which penetrated along the slightly dipping bedding planes and along the vertical joint cracks of the limestone. Under hydrostatic pressure and along a westerly sloping watertable the earlier waters seeped through and dissolved small passages at or slightly below the watertable. These small passages joined others already made and enlarged in the downstream direction. When the initial, small, tube-like channels became enlarged along the permissive bedding planes and joint cracks, waters from the stream entered in larger quantities and further enlarged them, eventually to such extent that all the normal waters of the stream and great quantities of flood waters are now carried through them. The development of the underground system beneath the sinkhole plain has been progressive in an upstream direction, having been initiated far down the dry-bed from the present perennial sinks of the stream. Some of the earlier sinks developed in or near the dry-bed channel are now the sites of large swallow-holes which convey great quantities of stormwaters to the underground system. These stormwaters reach them by flowing along the dry-bed channel following heavy rainfalls which overtax the capacity of the smaller holes near the upstream end of the dry-bed.

The present normal dry-weather sinks of Lost River are not characterized by abrupt descents of the stream waters into deep holes to a lower level. The waters rather simply flow into small nondescript openings only in part discernible. Upstream from the sinks, waters are fed into the stream channel from groundwater sources as well as from rainfalls and the channel is a receiving surface conduit quite similar to other surface streams. The channel serves as a limiting level of the watertable of the region nearby. In the area of the sinks the channel is slightly above the watertable and the stream loses its waters to the subterranean system beneath it, though the openings leading to the subterranean system are relatively small. The loss of the surface waters in the stream at the upper end of the dry-bed channel is far from spectacular, though it is impressive.

The first known loss of the stream waters is in a shallow pool in the channel about one-half of a mile upstream from Fishers Ford bridge, near the center of the SW¼ of sec. 4, T. 2 N., R. 1 E., 2½ miles southeast of Orleans (Fig. 2). Only in prolonged dry seasons may this sink become evident. During such times the small flow of

the perennial stream above enters the pool, but none flows out at the lower end. No actual swallow-hole is discernible. It is possible that some loss of water from the stream occurs farther upstream from this site, but if such is the case it has never been in sufficient amounts to cause the stream to cease flowing. When the water disappears in this pool, many of the pools below also go dry. No holes have been observed in any of them for nearly 1½ miles down the dry-bed. The first actual swallow-holes in the dry-bed are in the NE of SW¼ of sec. 8, T. 2 N., R. 1 E. It appears that several openings have developed, probably along a bedding plane just below water level on the western side of the channel. Several of them are close together immediately below a rather large river island, and others lie 100 to 150 feet upstream in the western prong of the channel about the river island. The latter are frequently dry and the lower ones receive the waters during much of the low-water periods, as the flowing stream is then confined to the eastern channel about the island. Frequently, however, some of the waters flow upstream to these small sinks. The waters of the stream simply flow into these openings nearly on the level of the stream itself, and there is little evidence of descent to a level much below the channel itself. The watertable here is only slightly below the river channel, and the capacity of the subterranean channels developed along the bedding plane appears to be rather limited. A slight increase in the volume of water in the channel causes some of the water to flow farther downstream to other swallow-holes in the channel. These small receiving swallow-holes are not littered with timber and trash carried downstream by stormwaters, but are exposed, such as they are.

Stormwater Drainage along the Dry-bed

The dry-bed channel below the present dry-weather sinks of Lost River is a stormwater channel and is occupied only when the streamflow, during or after rains, overtaxes the capacity of the dry-weather sinks. The dry-bed channel is characterized by numerous small holes into which the stormwaters descend to reach the underground system. The locations of those observed have been indicated in Fig. 2. Doubtless numerous smaller unobserved holes occur into which waters descend. Some of those observed occasionally become obstructed and appear ineffective, and new openings are developed locally along the upper part of the dry-bed course. The smaller holes are usually on one side or the other of the dry-bed channel, and some of them are out of the channel entirely, but are connected with it by subsidiary stormwater channels, usually at a higher level than the dry-bed itself. In addition to the numerous small swallow-holes of the dry-bed, three large swallow-holes have been developed which receive large volumes of stormwaters following heavy rains in the drainage basin. These large swallow-holes are not directly in the dry-bed channel, but are connected with it by short subsidiary channels leading into them. These large swallow-holes are important gathering orifices of the underground system. They

are not necessarily directly over the main underground course of the subterranean system.

The stormwater swallow-holes immediately downstream from the dry-weather sinks are much more frequently used than those farther down the dry-bed. Of the large swallow-holes the Stein swallow-hole is used quite frequently, but the Turner swallow-holes, west of the bridge across the dry-bed on State Road 37, 3½ miles south of Orleans, are used only following rather heavy rainfalls. The Tolliver swallow-hole is used still less frequently, and when large volumes of storm-waters reach it, much passes by and follows the dry-bed throughout its course. Perhaps the dry-bed is flooded throughout on an average of about 3 times a year, though periods as long as a year or more occur in which the entire length of the dry-bed is not used. Below the Tolliver swallow-hole the dry-bed makes a broad northward detour through a meandering course more than 10 miles in length before returning to the line of the westward course of the main underground route (Fig. 2). Only a few swallow-holes are present along this section of the dry-bed, except for a group in the sharp westerly meander turn in the NE¼ of sec. 3, T. 2 N., R. 1 W. The western limb of this long northward detour of the dry-bed is cut sharply below the general level of the sinkhole plain. Although it has a few minor swallow-holes, it is chiefly characterized by stormwater resurgences which contribute flooding waters to the lower part of the dry-bed course. These waters rise from pits adjacent to the dry-bed and flow into it after heavy rains. These stormwater resurgence pits are referred to locally as "wet-weather rises". The waters come largely from the sinkhole plain and the sinking streams to the north and northeast of the course of the dry-bed. In the section of the dry-bed below the broad northward detour, several important openings are present from which stormwaters from the underground course of Lost River rise, and further flood this section of the dry-bed course. The dry-bed ends at the entrance of the perennial waters coming from the great Orangeville resurgence or rise which frequently pours out great volumes of muddy stormwaters derived from the karst valleys north of Orangeville.

When stormwaters overtax the swallow-holes along the dry-bed, the excess waters appear to build up a head or a front and surge down the dry-bed as a wave or series of waves, quickly flooding it to a considerable depth. The surging advance of the flood waters is probably in part a result of impeding vegetation growth in the dry-bed, which slows down the advance of the first normal overflow of small volume and allows an accumulated volume to make a sudden advance. Another factor, however, appears to be a main contributing cause of the sudden surging advance of the waters. The swallow-holes, their conduits and the cavernous routes of the underground courses are voids of great capacity. When these once become filled, stormwaters enter the swallow-holes in considerably reduced volumes, and great volumes of excess waters are shunted rather suddenly down the dry-bed channel. Farmers report the occasional drowning of stock along the dry-bed course by these rather sudden advances of surging waters.

The Swallow-holes of Lost River

Small Swallow-holes Below the Dry-weather Sinks. Some 15 or 20 holes have been observed along the dry-bed channel between the dry-weather sinks and the Stein swallow-hole (Fig. 2). These small holes are sufficient to absorb the waters from light rains discharged down the dry-bed channel, and, during the recession period following a flood, they continue to take waters for some time when the stream falls short of the Stein swallow-hole. Since the capacities of these holes are limited, the stormwaters descending the dry-bed flood them one after another, and their locations are usually well obscured in the rising waters soon after they become filled to capacity. During the waning periods when the flood waters are receding, the terminus of the stormwater stream recedes upstream hole by hole, abandoning them in reverse order. A view of one of these small swallow-holes is shown in Fig. 3. The flowing waters enter them rather quietly, or with only a

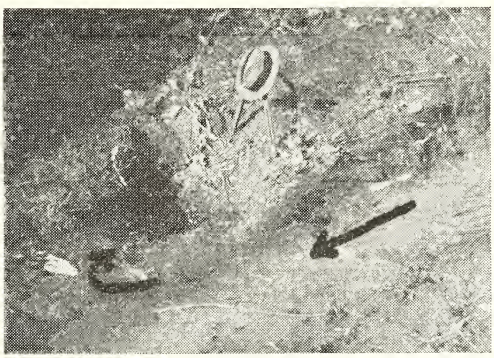

Fig. 3. View of a small swallow-hole receiving stormwaters along the dry-bed channel of Lost River about 1 mile below the principal dry-weather sinks, in the SE¼ of sec. 7, T. 2 N., R. 1 E., The stormwaters entering here at the moment form the terminus of the surface stream, but in a short time the terminous will retreat upstream to other swallow-holes and finally to the nomal dry-weather sinks. Note that the waters pour or fall into the small swallow-hole.

subdued gurgle. Vortices or whirlpools above the holes are only rarely observed, though they are undoubtedly present over some of the holes for short periods of time. They appear to be formed only when the waters below the orifices are able to get away faster than they can come through the orifices leading to the underground conduits. Some years ago a rather large noisy one was observed by the writer, and a view of it is shown in Fig. 4. It has not been observed since, though it has been looked for on many subsequent occasions.

A short distance upstream from the Stein swallow-hole, two holes on the left bank receive considerable quantities of water during flood periods. These swallow-holes are not in the dry-bed channel, but they are connected with it by a shallow channel at a higher level than the dry-bed. Small quantities of floodwater trash have accumulated about

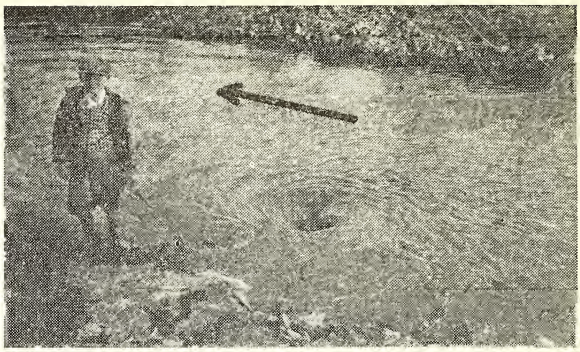

Fig. 4. View of a noisy vortex in the stormwaters of the dry-bed channel of Lost River 100 yards below the Johnson bridge in the SE¼ of sec. 7, T. 2 N., R. 1 E, about ½ of a mile down the channel from the principal dry-weather sinks. Vortices like the one shown are temporary and are rarely observed.

them. Opposite these holes on the right side of the dry-bed, a low area leads to the west and northwest which is widely flooded after heavy rains. No prominent swallow-holes are obvious, though undoubtedly waters do sink into an underground route below. Perhaps this low, frequently flooded area was once the site of a swallow-hole somewhat similar to that of the present Stein swallow-hole, but in the course of time it has been largely plugged by inwash and accumulating silts and muds brought to it by the stormwaters during floods. It has the appearance of being an older area which has been succeeded by the present active, large Stein swallow-hole a short distance to the south.

The Stein Swallow-hole. The Stein swallow-hole is located near the center of the SW¼ of sec. 7, T. 2 N., R. 1 E., just east of the Orleans-West Baden branch of the Monon Railway, 3 miles south of Orleans. It is slightly more than 1 mile west of the dry-weather sinks of Lost River, and nearly 2 miles by way of the dry-bed route. It is about 75 yards west of the dry-bed channel, and is connected with it by a crooked, mud-lined channel 120 yards in length. The ground plan is shown in Fig. 5. The swallow-hole is developed in the top part of the St. Louis limestone. The floor of the main pit is covered with a timber-raft about 100 feet long (north and south) and 60 feet wide. The western side of the pit, where most of the waters disappear, is a steep, rocky cliff, 20 to 25 feet in height (Fig. 6). The stormwaters enter quietly at the south end of the pit. They flow swiftly along the connecting channel and into the timber-raft, descending only a few feet below the level of the dry-bed. Subsidiary holes have been developed and are used during high-water periods, some of them only when the waters have overspread the channels.

The watertable at the Stein swallow-hole appears to be 20 or 25 feet below the dry-bed, and the underground channel leading away is

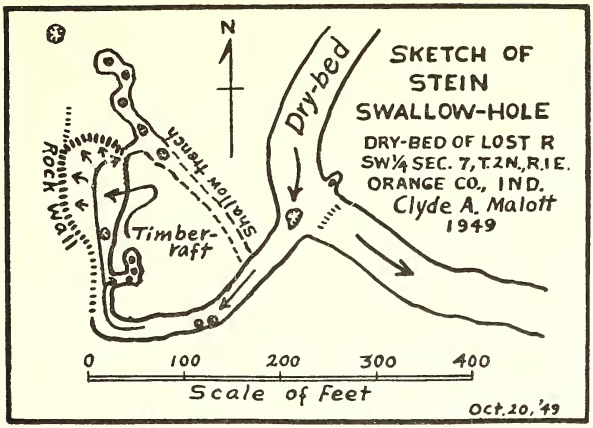

Fig. 5. Sketch of the Stein stormwater swallow-hole adjacent to the dry-bed about 2 miles down the channel from the principal dry-weather sinks of Lost River. Large quantities of stormwaters descend to the underground system through this swallow-hole following heavy rains. Its capacity is estimated at 750 cubic feet per second. The underground route and the watertable are 20 to 25 feet below the dry-bed here.

45 to 70 feet below the undulating surface of the sinkhole plain west of the swallow-hole. When floods come, the Stein swallow-hole is able to take a stream of water as much as 7 or 8 feet deep from the dry-bed. Its capacity is estimated to be about 750 cubic feet per second. When its capacity is exceeded, the extra stormwaters proceed on down the dry-bed to the Turner swallow-holes west of the bridge on State High-

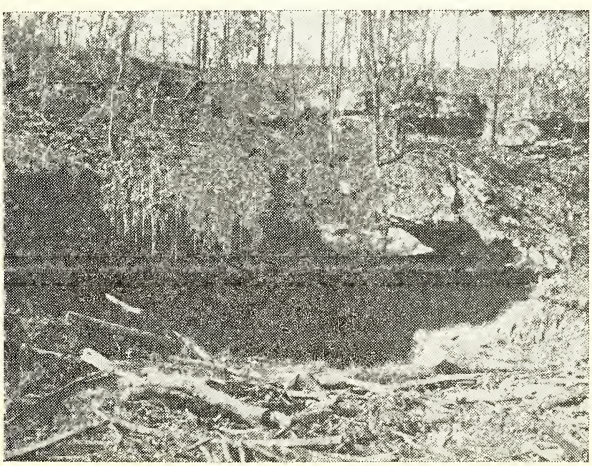

Fig. 6. View of the west wall of the Stein stormwater swallow-hole showing the overhanging St. Louis limestone and a portion of the timber-raft in the main pit of the swallow-hole.

way 37. Only 2 small holes have been observed in the dry-bed stretch of the channel of nearly 2 miles between these two major swallow-holes.

The Turner Swallow-holes. The Turner swallow-holes form a complex of more than 40 individual holes along and near the dry-bed channel in the NE¼ of sec. 13, T. 2 N., R. 1 W., about 1 mile southwest of the Stein swallow-hole, and in a loop of the dry-bed a short distance west of the bridge across the dry-bed on State Road 37, 3½ miles south of Orleans. A map of the chief swallow-holes and their relations to the dry-bed channel is shown in Fig. 7. All the swallow-holes are in the St. Louis limestone near the top of that formation. The largest loss of stormwaters from the surface is in a series of holes just west of the dry-bed. These holes are connected with the dry-bed by a short, crooked, subsidiary channel 12 to 15 feet in depth. Shows of bedrock walls are present along the western edge of some of these holes,

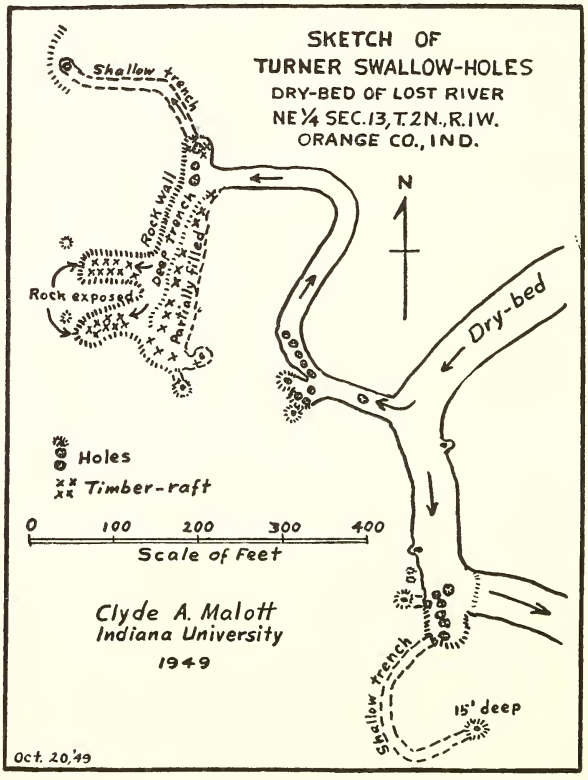

Fig. 7. Sketch of the main Turner stormwater swallow-holes along the dry bed of Lost River on the Earl Newlin farm west of the bridge across the dry-bed on State Road 37, 3½ miles south of Orleans. About 40 individual stormwater swallow-holes have been counted in this locality along and near the dry-bed course. The watertable here is about 35 feet below the dry-bed channel.

though the holes and walls are partially obscured by accumulated rafts, now much smaller than they were when first observed by the writer some 25 years ago. The larger holes extend sharply westward from the subsidiary channel. Some of them are nearly half-way across the narrow neck of the long southward meander loop of the dry-bed. About 200 feet farther down the dry-bed from the subsidiary channel is a second group of swallow-holes in the dry-bed channel or partly back from the channel, but connected with it by shallow subsidiary channels 10 to 12 feet above the bottom of the dry-bed. Other holes are present along the dry-bed for a distance of a quarter of a mile or more, and most of them are reached only during overflow stages. A number of them are on the east side of the dry-bed and a short distance from it. Several are in the soil only, and appear to be collapse holes where the sod or turf has fallen into bedrock channels below.

The total capacity of the Turner swallow-holes is equal to or greater than that of the Stein swallow-hole. During heavy floods they appear to have a greater capacity in the earlier stages, apparently becoming surfeited or stagnated in later stages. This change in capacity to receive stormwaters is probably a result of the filling of the underground conduits in the lower part of the system. Consequently a greater excess of stormwaters descend the dry-bed channel past the swallow-hole orifices than at the Stein swallow-hole.

A well about 100 yards northwest of the bridge across the dry-bed on State Road 37 gets its water supply from the St. Louis limestone at a depth of 130-135 feet. When first drilled in 1897 it was cased to a depth of 30 feet which placed the bottom of the casing near the level of the dry-bed. With every rain the water in the well became muddy. It was later cased to a depth of 86 feet, which shut out the underground stormwaters, and since then only clear waters have been pumped out. The water is quite "hard". The watertable itself appears to be at a depth of 30 to 35 feet below the dry-bed channel. As at the Stein swallow-hole, no openings are sufficiently large in the Turner swallow-hole complex to permit investigation of the subterranean system which carries the waters westward beneath the upland sinkhole plain. It is reported, however, that in early days a large cavern entrance was present in the woods at the Turner swallow-hole area, but this has been washed full of timber and silt and the locality now shows few signs of the existence of any such cavernous opening.

About 1 mile west of the Turner swallow-holes, a lengthy section of 3,200 feet of the underground system was explored and mapped by the writer and Robert Shrock in 1929. The opening to the underground system is an abrupt sinkhole on the farm of Austin Chastain, in the SW of NE¼ of sec. 14, T. 2 N., R. 1 W. The underground system is developed at three levels beneath the sinkhole plain, and the watertable is at an altitude of 555-560 feet, or about 40-45 feet below the dry-bed channel nearby. Details of this dangerously flooding cavern system were recently presented in a publication by the writer (8).

While no holes were actually observed in the long southward loop of the dry-bed channel below the Turner swallow-holes, some undoubted-

ly exist. Stormwaters as much as 3 feet deep have been observed adjacent to State Road 37 in the SE¼ of sec. 13, below the Turner swallow-holes, while none flowed across the road near the northwest corner of sec. 13. A short distance farther west, however, in the NE¼ of sec. 14, a group of 4 swallow-holes of considerable size is present in and adjacent to the dry-bed. Three of them lead southward from the dry-bed and one loops backward on the north side through a subsidiary channel. One of these holes was entered and followed for about 30 feet some 15 feet below the dry-bed. The dry-bed at this locality occasionally overflows to the south and storm waters enter two sinkholes developed at or slightly below the level of the dry-bed. Undoubtedly the stormwaters entering this group of swallow-holes and overflowing into the two deep sinkholes reach the underground system a short distance north of the explored section entered through the sinkhole on the Austin Chastain farm a short distance south of the dry-bed.

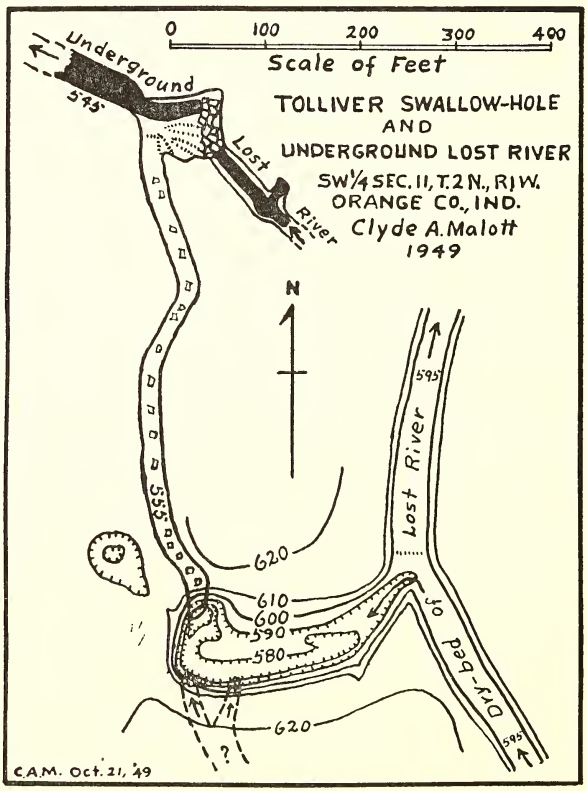

Fig. 8. Sketch of the Tolliver stormwater swallow-hole and its underground cavernous route to a mapped section of underground Lost River. The Tolliver swallow-hole is 7½ miles down the dry-bed channel from the principal dry-weather sinks of Lost River. Underground Lost River is 50 feet beneath the dry-bed here.

The Tolliver Swallow-hole. The Tolliver swallow-hole is located in the SW of SW¼ of sec. 11, T. 2 N., R. 1 W., just west of the dry-bed channel, with which it is connected by a short, descending channel. Curiously, all of the large swallow-holes are at the apices of westerly loops in the dry-bed channel. The Tolliver swallow-hole is 3¾ miles down the dry-bed channel from the Turner swallow-holes and about 7½ miles from the dry-weather sinks of Lost River. The dry-bed channel here is at an altitude of 595 feet, only 25 feet lower than at the dry-weather sinks. The lead from the dry-bed descends sharply to an orifice which receives the entering stormwaters. The orifice is usually obscured by a considerable timber-raft, though at times it may be readily seen. The lead from the dry-bed channel is approximately 300 feet in length, curving southwest to west and then sharply northward to the orifice. The opening leads downward to a cavernous channel developed at an altitude of 555-560 feet, which leads northward for 565 feet and joins the underground route of Lost River at an altitude of 545 feet. A map of the Tolliver swallow-hole and its relations to the short explored section of Lost River are shown in Fig. 8. Underground

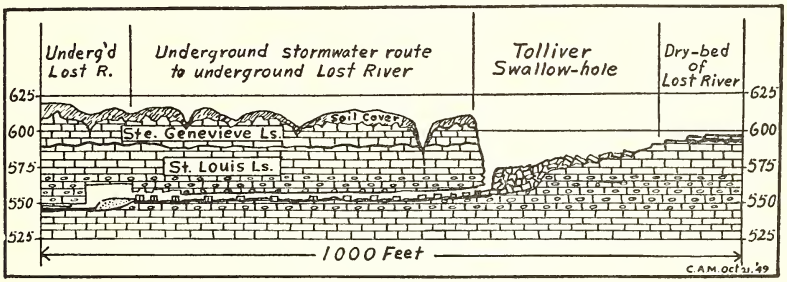

Fig. 9. Diagrammatic section extending from the dry-bed of Lost River through the Tolliver swallow-holes and along its cavernous route to underground Lost River. The entire section shown in the diagram is 1,000 feet in length. The contact of the St. Louis limestone below and the Ste. Genevieve limestone above is at an altitude of 590 feet.

Lost River is 50 feet beneath the dry-bed at the Tolliver swallow-hole. The vertical and geological relations are depicted in Fig. 9.

The Tolliver swallow-hole is the most spectacular and interesting of the many swallow-holes along the dry-bed course of Lost River. Its western end is an abrupt rock wall about 35 feet in height, and its orifice at the bottom is the only one of the many swallow-holes sufficiently open to permit entrance and underground exploration. The opening is uninviting and the passage leading to underground Lost River is difficult and dangerous. Both the opening and the passage are damp, drippy and muddy. The cavern channel is developed in a cherty phase of the St. Louis limestone about 30 feet below the contact with the Ste. Genevieve limestone which forms the general upland sinkhole plain of the locality. Ragged, sharp, cherty masses extend out from the sides and ceilings of the low, cavernous route, and the floor is strewn with loose cherty slabs and many large rock masses.

The route is 10 to 25 feet in width and only 3 to 4½ feet in height. Passage along it is slow, tedious and painful. When first entered and partially mapped by the writer and Robert R. Shrock, Aug. 12, 1929, an accumulation of carbon dioxide, derived from the decaying timber raft above and in the orifice and along the upper part of the passage, made the exploration and mapping hazardous, and the work had to be discontinued. Full exploration and mapping underground was accomplished by the writer and Robert Bates, July 16, 1931, at which time the air was without contamination and danger from "damps".

Entrance into the cavernous route leading from the Tolliver swallow-hole to underground Lost River is not always easy or even possible, because of the accumulated timber-raft which may remain in place over the orifice for months or even years. At times, however, the swallow-hole is relatively free from accumulated timber and trash, and entrance may be made with little difficulty. The writer made many trips to the swallow-hole before it appeared possible to enter it, though on some of the trips lack of sufficient courage may have been a factor delaying entrance and exploration. On the two occasions that it was entered, it was noted that packed logs filled a considerable part of the opening along the north wall, indicating the presence of a broad opening 30 feet or more in width, if the rafted timber could be entirely removed.

The orifice of the swallow-hole was entered through an opening in the timber-raft, descending vertically about 10 feet (Fig. 10). The

Fig. 10. View of the timber-raft in the Tolliver swallow-hole showing the hole through which entrance was made to reach underground Lost River 565 feet to the north. The view was taken Aug. 15, 1930. The timber-raft at the present time is much reduced in size.

cavernous channel averages but little more than 3 feet in height for a distance of 435 feet. No solid rock shows on the floor. In the first 100 feet large mud-covered rock blocks are much in evidence, while the remainder of the low section has loose slabby rock on the floor with only a few large blocks. Everywhere the floor and rocks are covered with sticky mud an inch or more in thickness. The ceiling is composed of a roughened limestone bed with scarcely a break for the 435 feet. The roughness is due to the presence of porous chert masses which extend downward several inches from the bed of limestone. The low ceiling is also mud-covered. Logs and timber are present along the rough-hewn route, though after the first 100 feet these do not hinder progress. At 435 feet from the entrance the cherty limestone forming the ceiling ends and the ceiling rises 7 to 10 feet above the slippery mud floor. On approaching underground Lost River the channel widens and enters a great rectangular room 80 feet long (east-west), 75 feet wide (north-south), and 15 to 20 feet in height. Lost River occupies a trench on the farther or northern side of the room, and the noise of its waters rippling over the cherty gravel in a descent of less than 1 foot may be heard in the cavernous channel for a distance of 200 feet or more. The flowing waters come from the east and pass under the western wall of the room into a still pool about 40 feet in width and 1 to 3 feet in depth. The ceiling in the downstream passage is low and in about 75 feet descends to within 1 foot of the water, preventing further traverse in the downstream direction.

The floor of the large room is composed of mud bars between shallow trenches which come from the eastern end of the room. A large mud bar is banked high at the right of the swallow-hole channel just inside the room. The trench occupied by Lost River is 20 to 25 feet in width, but is partially filled with mud in which a narrower channel is cut. Underground Lost River is at an altitude of 545 feet, only 5 feet higher than the low water level in the deep pit in the Wesley Chapel "gulf" 1½ miles to the west. The underground channel apparently marks the level of the watertable which has been drained down 50 feet below the dry-bed and 70-80 feet below the undulating sinkhole plain adjacent to the Tolliver swallow-hole. Lost River comes through a mass of fallen rock at the eastern end of the big room. The rocky mass is mud-covered and extends 10 feet or more above the river waters. The waters of Lost River flow into the rock mass just beyond the southeastern corner of the big room, and the upstream section of the cavern channel extends southeast. The channel is 20 feet in width and has a mud-covered floor over which the waters quietly flow. Approximately 100 feet upstream the waters rise out of a pool about 15 feet in width on the north side of the channel. Waters also come in from the right through a low cavern channel which could not be reached because of soft miring mud composing the floor beneath the waters of the stream. Only about 300 feet of underground Lost River could be examined. The course and the chief features are depicted in Fig. 8.

The lead into the Tolliver swallow-hole starts on solid rock in the dry-bed. The rock ledges compose the very top of the St. Louis limestone. The rock exposed in the dry-bed just below the entrance to the swallow-hole is composed of the base of the Ste. Genevieve limestone. The floor of the lead passes into loose slabby limestone. The rock-strewn stormwater trench follows closely the steep south wall. Towards the western end of the swallow-hole the outer walls are nearly 100 feet apart, and a broad section of the floor of the swallow-hole is composed of a vegetated ridge of silt with a shallow secondary trench on the north side. The accumulated silt appears to rest upon broken rock. Following heavy rains muddy waters enter the swallow-hole from the south side through broken-down masses which obscure the two cavernous channels which convey them. Long before waters descend the dry-bed the swallow-hole becomes partially filled by the waters entering from the hidden cavernous channels. It is quite probable that the hidden channels connect with those explored on the Austin Chastain

Fig. 11. View of the Tolliver swallow-hole showing the waning stormwaters entering from the dry-bed following heavy rains, March 21, 1933. Slimy silts cover the sides and surfaces as much as 15 feet higher than the entering waters, indicating the much higher level of the stormwaters before the view was taken. The timber-raft is imperfectly shown floating in the stormwaters near the distant (western) terminus of the swallow-hole.

farm a little more than ½ of a mile to the southeast, and that the waters re-appearing here for a short stretch enter the underground system at the Turner swallow-holes. Mr. Martin Tolliver reported that agitated waters whirl in the pit after heavy rains. This action always precedes the coming of stormwaters down the dry-bed course. A view of the swallow-hole is shown in Fig. 11, with a small flow of stormwaters entering from the dry-bed. When the stormwaters in the dry-bed descend in large volumes, the swallow-hole is soon filled to its capacity and excess waters proceed on down the dry-bed past the swallow-hole and course down the entire channel. The flooding of the entire dry-bed channel usually does not occur more than 2 or 3 times

a year, and occasionally periods of a year or more elapse without the flooding of all the dry-bed channel. During heavy floods the stormwaters in the Tolliver swallow-hole stand as much as 65 feet above the low-water course of underground Lost River, and the great hydrostatic head exerts a strong pressure on the underground stream.

The Tolliver swallow-hole appears to have originated through the collapse or stoping of the roof-rock over a broad or compound section of the cavernous channel some 35 to 50 feet beneath the sinkhole plain. The collapse pit was then breached by stormwater overflows from the dry-bed. The swallow-hole is in reality one of the gulfs of Lost River. It was referred to as a gulf by Richard Owen, who made a wood-cut illustration of it 90 years ago (10, 141). Elrod (3, 212) referred to it as "the fourth sink of Lost River." It represents, however, only an early stage in the development of a gulf as compared to the large one over underground Lost River at the Shirley or Wesley Chapel gulf 1½ miles to the west.

Swallow-holes below the Tolliver Swallow-hole. Below the Tolliver swallow-hole the dry-bed channel of Lost River makes a broad northward detour away from the direct underground course for a distance of about 3 miles (Fig. 2). The dry-bed channel in the northward detour is a winding course 10 or 11 miles in length. It then continues some 3 miles farther in a winding, deeply intrenched course before receiving waters at the Orangeville rise. The eastern limb of the northward detour continues the low-gradient course for a channel distance of nearly 4 miles below the Tolliver swallow-hole, reaching an altitude of about 580 feet. The western and southern sections of the northern detour of the dry-bed channel show a marked increase in the gradient, so that in about 6 miles of its route it descends 70 feet to an altitude of 510 feet, and becomes sharply intrenched below the general level of the sinkhole plain which is itself becoming fragmentary because of the presence of sandstone-capped ridges rising above it. Swallow-holes in this course of the dry-bed, except for one locality, are few in number. The western limb of the northern detour is characterized instead by stormwater resurgences or rises.

A single swallow-hole is present just east of the dry-bed and south of the cement bridge in the NW of NW¼ of sec. 11, T. 2 N., R. 1 W., nearly 1 mile north of the Tolliver swallow-hole. It does not appear to take a significant amount of water and floods easily. A series of swallow-holes taking considerable quantities of stormwaters from the dry-bed is present in the western meander of the dry-bed chiefly in the E½ of NE¼ of sec. 3, T. 2 N., R. 1 W. At least 5 swallow-holes are present in this bend, and some of the sinkholes to the west of it are lower than the dry-bed itself. The dry-bed here has an altitude of 585 feet. One deep rocky sinkhole just west of the apex of the westward loop of the dry-bed descends at least 20 feet below the dry-bed. The stormwaters lost from the dry-bed here pass underground to the northwest and return to the surface in the stormwater resurgences or "wet-weather rises" on the former Mathers farm in the SW of SW¼ of sec. 34, T. 3 N., R. 1 W. A short distance south of the westerly

bend is a low alluviated *cul de sac* connected with the dry-bed, which contains several small swallow-holes as low as or lower than the dry-bed (Fig. 2). This *cul de sac* has the appearance of a partially filled swallow-hole complex into which waters from the dry-bed formerly entered in considerable volumes. It is probably a nearly abandoned swallow-hole terminal through which waters were once directed northwest through the Peacher caves underground route and on to the resurgence on the former Mathers farm. The Peacher caves in the southern part of the NE of NW¼ of sec. 3, T. 2 N., R. 1 W., are remnants of a broken down and partially filled cavern system, marking a former high-level underground route of Lost River across the northern part of the northern detour of the dry-bed. This route was local and lost out when the Tolliver swallow-hole and other swallow-holes farther up the dry-bed became sufficiently developed to take much or most of the stormwaters through the present more direct and deeper underground route.

Except for one locality, no swallow-holes of any significance are present along the dry-bed below those in the sharp bend in the NE¼ of sec. 3. Far down the dry-bed in the area of deep intrenchment and normally occupied by stormwater resurgences, a small group of 2 or 3 swallow-holes and a large collapse pit, probably over the main underground channel of Lost River, are present on the south side of the dry-bed near the junction with a small ravine in the NW of SW¼ of sec. 8, slightly less than 1 mile southeast of Orangeville. The swallow-holes are small, only a few feet above the dry-bed, and contain much mud and intermingled small trash. Another hole is present in the dry-bed about 150 feet downstream. The large collapse sinkhole immediately west of the small swallow-holes is developed in the edge of a steep bluff rising more than 100 feet above the dry-bed, and its conical bottom descends to the level of the dry-bed (505 feet above sea level). This large collapse feature is about 150 feet across and its partially broken-down eastern rim rises 25 feet above the dry-bed. Its conical bottom is composed of angular blocks of moss-covered rock fallen from above. The western side of the collapse pit is a combined talus slope of loose rock and a perpendicular wall of Ste. Genevieve limestone strata rising 85 feet above the rocky bottom. Above this, it rises steeply back to 105 feet above the bottom to a capping of the massive Mooretown sandstone of Lower Chester age which exhibits a tension crack 10 feet wide, indicating creep and slippage of the rock forming the steep eastward-facing wall. Undoubtedly a large cavity has collapsed to form this feature close to the dry-bed. Quite possibly it is immediately over the underground route of Lost River itself. It is directly in line with the terminal rise of Lost River along the westward course of the underground route (Fig. 2). The feature marks the beginning stage of a gulf. The swallow-holes and the large collapse sinkhole make a distinct recess in the steep valley side and indicate the possibility that one of the earlier sinks of Lost River took place here. Midway up the cliff of the steep wall of the collapse sinkhole some openings are present which suggest a high-level cavern, though these openings

were not investigated. The location of the features here in a western bend of the dry-bed is only a little more than ½ of a mile east of the terminal rise of Lost River on the Allen farm, whereas the route around the course of the dry-bed and the stream is in excess of 3½ miles. The location and the features are quite suggestive of an earlier developed swallow-hole which has nearly lost out as a place of sinking waters. Continued down-cutting of the dry-bed course and the development of other sinks farther upstream and higher on the perched sinkhole plain were factors in the near disuse of the sink at this locality.

The Course of Underground Lost River

Underground Lost River in a general sense is a system of subsurface drainage which acquires the greater part of its discharge from an area of approximately 120 square miles (excluding Stampers Creek system), in part diverted from surface streams and in part from sinkhole drainage. A much smaller part of its discharge is lithic drainage of waters more slowly feeding into the system from the rocks themselves. The lithic drainage is in part composed of phreatic waters and in part from local seepages and underground springs coming from higher levels than the watertable. The clear waters which filter through the roof-rock of the underground passages drip slowly into the system locally, frequently coming from the ends of stalactites. Also many small underground springs feed into the cavernous channels, representing local lithic drainage from above the watertable. Many of these small seepages and underground springs cease to flow during long continued dry periods. The source of some of the incoming seepages and underground springs is from surface springs issuing from the Chester formations in the ridges in the western part of the area, which, after flowing over the surface for short distances, sink into the limestone and descend to the underground passages 100 feet or more below the surface. The lithic drainage, therefore, is only in part composed of phreatic waters. Moreover, the clear waters of the lithic drainage cannot be distinguished from the clear waters entering the sinks at the upper end of the underground system after they have entered the main lines of discharge of the underground routes.

The passages of the subsurface system are well co-ordinated and integrated into a regional system spreading as a great network pattern throughout the karst area of the drainage basin. The larger and deeper conduits have become the main runways which readily carry incoming waters through long distances to the orifices of discharge or terminal resurgences. The network system is three-dimensional, dominantly developed along the slightly westerly-sloping bedding planes and the vertical joint system, both well displayed in the limestone exposures at the surface and in the caverns beneath. Integrated parts of the network system slope to tributary subsurface routes, and the master routes descend westerly from the higher karst areas on the east to the resurging terminals at low levels on the west. The network system with its larger and major cavernous courses is relatively well opened,

so that surface waters readily enter from the inumerable sinkhole hoppers and the sinking surface streams. The flooding waters of heavy rains are taken below and conveyed through the subterranean system for many miles to the orifices of discharge.

In the eastern edge of the sinkhole plain where many separate surface streams have their first sinks, the subterranean waters come from a wide area and are directed through individual routes which apparently merge into lines of more concentrated passage in the western area of the system. Although several stormwater resurgences are known, they are relatively narrowly restricted along the lower course of the dry-bed of the intermittent surface course. Only two perennial and terminal resurgences are present in the system, and they are only ¾ of a mile apart, at and below Orangeville, where Lost River becomes the watertable limit of a low-level surface stream.

The main course of underground Lost River undoubtedly has its beginning in the locality of the first sinks where surface waters descend below the bed of the stream. The terminus of the sinking stream reaches nearly two miles west of the eastern edge of the sinkhole plain which absorbs the rainfall and the stormwaters of smaller sinking streams at altitudes 50 to 75 feet higher than the sinks in the Lost River channel. The principal dry-weather sinks near the center of sec. 8, T. 2 N., R. 1 E., are 7 miles due east of the terminal resurgence of Lost River, and the brief appearance of Lost River waters in Wesley Chapel gulf is directly on the line between them. The Stein, Turner and Tolliver swallow-holes are somewhat south of the due west line, and it is likely that the notable amounts of stormwaters coming from these great swallow-holes and from many lesser ones along the dry-bed enter the main course from shorter or longer tributary channels. The main course of the underground stream is undoubtedly westerly, though it very probably has some detours from a due west general course. Also, it probably has parallel passages both at or near the watertable and at higher levels occupied during high-water periods. The main course westward from the principal dry-weather sinks of Lost River is occupied continuously by waters from the surface stream. This continuous stream is very probably along the lowest depressed watertable section of the westerly descending system. Locally it may have some development actually below the watertable in certain stretches of the underground route. In any case it is a westerly descending route having a vertical descent of at least 130 feet in the 7 miles of its westerly course.

Little is known about the main underground course of Lost River in the first 3½ miles of its course to near the Tolliver swallow-hole. A short stretch of its course has been described near the latter place where it is a well-developed cavernous channel 50 feet below the dry bed. It has a descent of 75 feet in this westerly course from 620 feet to 545 feet in altitude. Westward from the short section reached through the Tolliver swallow-hole, the main course is fairly well determined. It passes close to and under the deep Nicols cavern half a mile west, near the center of the S½ of sec. 10, T. 2 N., R. 1 W., and thence slightly

north of west for 1 mile to the Shirley or Wesley Chapel gulf, where it rises to the surface in a deep pit, a short distance east of the center of sec. 9. Sinking immediately, it continues west, passing close to a stormwater resurgence a short distance south of the center of sec. 8, to its final resurgence on the east bank of the surface stream south of the center of sec. 7, ¾ of a mile south of the village of Orangeville and 2 miles west of the Wesley Chapel gulf.

The Nichols cavern leads northeast and rather steeply downward from a broad, circular, steep-sided collapse sinkhole to a deep, muddy pit close to the northern terminus of the cavern 205 feet from the entrance. The bottom of the pit is 100 feet below the surface and at an altitude of 560 feet. Although a small stream carries stormwaters into the broad cavern from a small drainage area, no waters stand in the deep pit during low-water periods. During flood periods, however, muddy waters from underground Lost River rise in the pit to a height of about 20 feet. These waters recede with the drop in the flooding stormwaters of underground Lost River, clearly showing the connection of the cavern with the underground stream. The underground stream is probably only a short distance north of the cavern. Just west of Nicols cavern the underground course passes 200 feet beneath the crest of a ridge capped with Chester sandstone and forming a part of the irregular margin of the Chester escarpment. A little more than ½ of a mile farther west the underground stream issues from the deep pit in Wesley Chapel gulf.

The Wesley Chapel Gulf

The Shirley or Wesley Chapel gulf, the rise and sink of Lost River within it, and the network of cavernous routes of underground Lost River west of the gulf constitute the most interesting features of the entire Lost River region. The gulf has been a subject of local interest for more than a century. In the early days it was a source of water supply for the community and was known as the Shirley gulf. But since its first introduction into geological literature by Elrod in 1876, it has been known chiefly as the Wesley Chapel gulf, named for its nearness to the Wesley Chapel Church at the cross-roads a short distance to the north. Elrod (3, 225) states that Lost River "comes to the surface at Wesley Chapel gulf, in section 9, township 2 north, range 1 west, where the superincumbent rocks have fallen in and forced the stream to the surface. The subterranean stream may also be reached at this point through a cave in the side of the hill. Some years ago a boat was taken in and the channels explored for some distance to a fall beyond which it was impossible to pass." Elrod (4, 263) mentioned Wesley Chapel gulf in a subsequent paper bearing on the features of the Lost River region. A brief description of the gulf was presented by the present writer (5, 208) in a general description of the features of Lost River, and again in a paper describing cavern stages (6, 202), the Wesley Chapel gulf was briefly described and stated to be the most spectacular topographic feature of the entire Lost River basin. In 1929

the present writer and Robert R. Shrock entered and mapped much of the network of cavernous passages west of the gulf. Additional work was done in the underground system and a detailed map of the gulf was prepared. Rather full descriptive details of the gulf and the underground passages occupied by Lost River and available from it were published by the writer in 1932 (7). In the meantime, Davis (2, 538-539), in his memorable treatise on the origin of limestone caverns, published a section of the network of the underground system of Lost River and

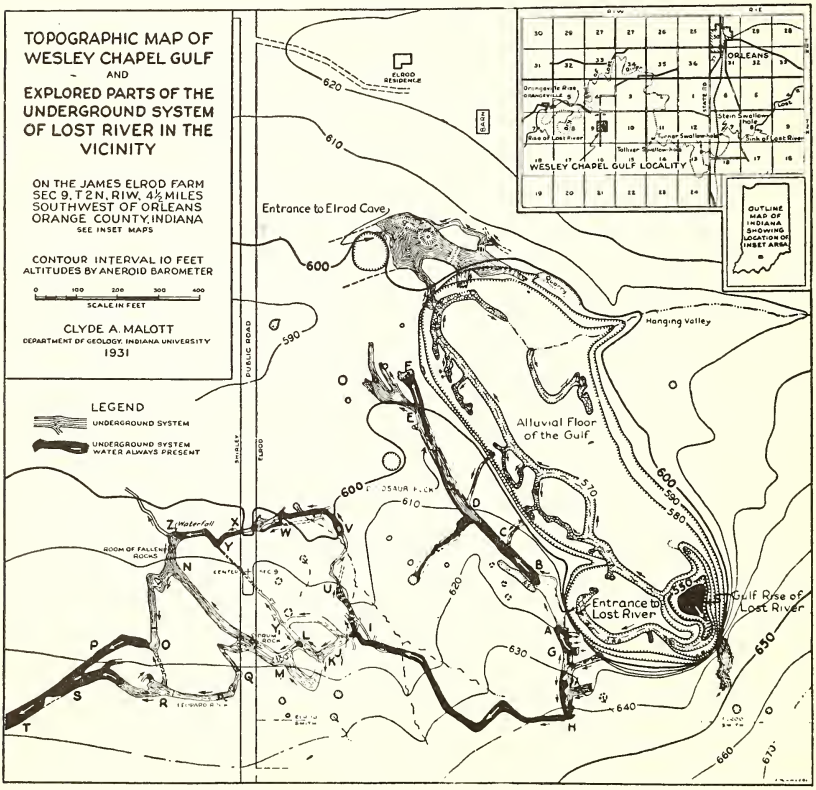
TOPOGRAPHIC MAP OF WESLEY CHAPEL GULF
AND
EXPLORED PARTS OF THE UNDERGROUND SYSTEM OF LOST RIVER IN THE VICINITY
ON THE JAMES ELROD FARM SEC 9, T 2 N, R 1 W, 4½ MILES SOUTHWEST OF ORLEANS ORANGE COUNTY, INDIANA
SEE INSET MAPS
CONTOUR INTERVAL 10 FEET
ALTITUDES BY ANEROID BAROMETER
SCALE IN FEET
CLYDE A. MALOTT
DEPARTMENT OF GEOLOGY, INDIANA UNIVERSITY
1931
LEGEND
UNDERGROUND SYSTEM
UNDERGROUND SYSTEM WATER ALWAYS PRESENT
ELROD RESIDENCE
Entrance to Elrod Cave
Hanging Valley
Alluvial Floor of the Gulf
Entrance to Lost River
Gulf Rise of Lost River
ROOM OF FALLEN ROCKS
DINOSAUR ROOM
ORLEANS
WESLEY CHAPEL GULF LOCALITY
OUTLINE MAP OF INDIANA SHOWING LOCATION OF INSET AREA

Fig. 12. Topographic map of the vicinity of Wesley Chapel Gulf, with a smaller scale inset map of the general region.

presented a brief description of the gulf from data furnished by the present writer at Davis' request. The topographic aspects of the gulf and the explored and mapped network of underground Lost River, as presented in Fig. 12 of the present paper, are from the map published by the writer in 1932.

The features of the gulf, the associated aspects of underground Lost River, and its probable method of development are presented again in some detail. Wesley Chapel gulf is an abrupt, steep-sided, tree-lined depression in a gently undulating, soil-covered area of cultivated farm and

pasture land in the western edge of the Lost River sinkhole plain closely adjacent to the irregular eastern margin of the Chester escarpment. Its steep-sided perimeter, largely composed of the broken-off, weather-fretted edges of limestone strata, encloses an area of 8.3 acres. The gulf is 1,075 feet in length, extending north-northwest, and averages 350 feet in width. Its ends are rounded, forming semicircles of nearly equal size, between which it narrows slightly. On the eastern side near the northern end, stormwaters from a hanging valley have cut a V-shaped notch in the perimeter. A counterpart of this notch is present on the opposite side near the southern end where a mass of collapsed and broken limestone extends out into the gulf area. The altitudes about the perimeter vary from 595 feet along the northwestern edge to 640 feet on the southeastern edge, and the walls form a continuous circumscribed cliff or bluff 25 to 95 feet in height about the floor of the depression. The floor of the depression embraces an area of 6.1 acres and is largely composed of flat alluvial soil in which are stormwater trenches and a deep, mud-lined pit from which the waters of Lost River rise.

The steeply-sloping conical pit containing the rising waters of Lost River is at least 125 feet in diameter at the level of the alluvial floor of the gulf, but at the level of the low-water stand of the pool, 30 feet below, the diameter is approximately 75 feet. The rise-pit is under the shadows of the steep and partially overhanging high wall of the southeastern edge of the gulf, and along the cliff it has two wings which curve slightly into the gulf floor. The northern wing pours muddy waters into the pit during flood periods, while the southern wing receives the waters which issue from the pit during low-water periods, and, in its westward curve into the alluvial gulf floor, it shallows and continues as a stormwater channel with several swallow-holes. This channel terminates in a northern and easterly curve on the western side of the gulf floor, 250 feet west of the pit from which it comes. Here it contains several large swallow-holes partially obscured by an accumulated timber raft. Another stormwater trench leads northwest from the rise-pit and extends parallel with the western side of the gulf, well out in the alluvial floor, to the north end of the gulf where it recurves back out into the alluvial floor, and thence to several well-defined swallow-holes along the eastern side of the gulf a short distance south of the hanging valley. At the north end it contains numerous swallow-holes, and along its course parallel with the western side of the gulf several short distributaries and loops reach numerous swallow-holes close along the western wall. One distributary cuts directly across the middle of the gulf floor to the swallow-holes on the eastern side. (Fig. 12). Several acres of the alluvial floor of the gulf were formerly planted in corn every year, but in recent years the rich alluvial floor has been abandoned and is becoming a thicket of growing bushes and trees.

During low-water periods the pool in the rise-pit is a beautiful azure blue in color and perfectly calm. The waters issue quietly and enter the southern wing and disappear with only slight turbulence in

the mud-covered talus rock at the foot of the cliff. After rains the issuing waters in the pit increase in volume and become muddy and silt-laden. Heavy rains fill the pit to overflowing and discharge down the stormwater trenches in the alluvial floor of the gulf. Occasionally the waters flood the entire alluvial floor to several feet in depth. At such times the waters issuing from the pit are violently turbulent and great boils of rising waters discharge from it. As much as 4,000 to 5,000 cubic feet per second issue from the underground course of Lost River during times of heavy floods when all the swallow-holes of the dry-bed are receiving their maximum capacities. These waters, overflowing the gulf floor, are returned to the underground system through at least 100 swallow-holes in the gulf floor and they fill the underground system west of the gulf to its full capacity.

The walls of the Wesley Chapel gulf are composed of the Ste. Genevieve limestone which in the locality has a total thickness of 115 feet. The lost River chert bed is displayed at several places slightly above the level of the alluvial floor of the gulf and 20 feet above the base of the Ste. Genevieve limestone. Underground Lost River is developed in the St. Louis limestone approximately 40 feet below the floor of the gulf. The alluvium of the gulf floor appears to be about 35 feet in depth and probably lies upon broken masses of rock into which alluvial silts have filtered and compacted. The alluvial accumulation of the gulf floor completely obstructs the passage of the underground waters of Lost River through the area occupied by the gulf. The waters of underground Lost River either have to pass around the compacted silts through underground passages developed in the St. Louis limestone about the ends of the gulf or have to rise out of the pit and flow across the top of the alluvial floor to the swallow-holes where they are conveyed to the underground system mainly on the western side of the gulf. In low-water periods the waters of the stream pass around the south end of the gulf, but in flood periods passage appears to be in part around both ends of the gulf and in part over the alluvial floor.

The Wesley Chapel gulf and its deeply alluviated floor of clays and silts clearly indicate the destruction and removal of approximately 720,000 cubic yards of native limestone. The width of the gulf is far greater than any known section of underground Lost River with which the gulf is genetically related. The gulf is not merely a fallen-in cavern whose collapse rock has been dissolved away. The shape of the gulf and its present relations to the underground water courses suggest something concerning the nature and method of its development. It very probably was initiated as one or more collapse sinkholes of rounded outline over a broad and weakened portion of the underground system. The collapsed rock obstructed free passage of the waters and their energies were concentrated about the collapse rock which in time undermined the walls about the collapse depression. Further collapse increased the perimeter of the initial collapse depression. If two or three collapse areas were formed in a row, their perimeters in time were merged to form a large and enlongated depression with semi-circular ends, such as Wesley Chapel gulf possesses. Horns of rock

would extend out in the depression for a time, but eventually they would melt away through enhanced weathering and solution. One such horn of rock, tumbled and broken, still extends into the floor of Wesley Chapel gulf.

A study of the behavior of the flows of Lost River waters around and about the impassable barrier of the compact and insoluble silts of the gulf floor indicates that practically the entire gulf is surrounded by active stream waters which in times of flood forcibly lave and dissolve the entire perimeter of the gulf through a rock thickness up to 40 feet or more. Waters issuing from the deep pit immediately enter the talus rock at the southeast side and in times of high floods enter a cavern opening 30 feet above low-water level. These waters pass around the south end of the gulf and join the explored passages of underground Lost River on the west (Fig. 12). Great quantities of stormwaters descend through the swallow-holes along the western wall of the gulf and enter the underground system either through masses of subsurface talus between the alluvium and the underground passages or through large tubular passages connecting with the main system. At the northern end of the gulf large quantities of stormwaters enter Elrod cavern (Malott, 7, 308-311) through several passages where they are undermining the steep perimeter of the gulf. Elrod cavern is well flooded with stormwaters, and its great width of up to 125 feet indicates the probability of near-future collapse close under the northern wall. Already a circular collapse 90 feet in diameter has taken place in the illy supported roof-rock of the cavern only 125 feet northwest of the northern end of the gulf (Fig. 12). An underground stream very probably passes about the eastern and northern perimeter of the gulf, as indicated by the swallow-holes just south of the V-shaped notch in the perimeter made by the waters entering from the hanging valley. It is probably this same stream which may be seen at a low level along the undermined northern side of Elrod cavern near the eastern end.

The processes which have formed the gulf are still in operation and the growth of the gulf has been progressive. It is a product of progressive perimeter collapse and dissolution of the fallen rock. The enveloping underground streams are thin but vigorous dissolving agents which insidiously sap the foundation of the gulf walls. These walls are hollowed out and weak at their bases. They do not stand on solid rock. 720,000 cubic yards of rock have been undermined, tumbled in, dissolved away, and a new level created. As such, Wesley Chapel gulf is a local, circumscribed valley stretch, a *uvala*, surrounded by rimming rock which fails to imprison the streaming waters which work to enlarge it into a lengthening valley expanse. It is yet but a window in which a hidden stream in low-water and in fearsome flood has been brought into the light of day.

Underground Lost River at Wesley Chapel Gulf

The artesian issue of the waters from the deep pit under the high cliff at the southeastern end of Wesley Chapel gulf is evidently

from the main subterranean course of underground Lost River. The waters of this course are forced to rise 20 feet or more from the submerged passage during low-water periods, and as much as 50 feet or more during flood periods. The blocking of underground Lost River by the alluvial material composing the floor of the gulf is quite complete. The underground channel is filled with ponded waters very probably as far east as the Tolliver swallow-hole, where aneroid determinations indicate the pooled waters at the lower end of the explored section of the underground stream are only 5 feet higher than the low-water pool at the gulf. Such ponding indicates that no parallel or subsidiary underground channels at low levels by-pass the dam formed by the floor of the gulf. It appears quite probable that before the development of Wesley Chapel gulf the main channel of underground Lost River turned northwestward along strike joints and connected with the broad section of Elrod cavern, and thence slightly southwest along dip joints, as indicated in Fig. 12. If this conjecture is true, then much of the cavern system explored west of the gulf, as shown in Fig. 12, and now receiving the waters issuing from the deep pit of the gulf, is relatively new and still in process of development. Such an interpretation is further borne out by the fact that the altitudes of the floors of the system west of the gulf are near the level of the pool itself, except in the remote sections where abrupt descents are made to a lower level. Under this interpretation the angular anastomosing network and the partially mapped distributaries have been fashioned from various local passages and primitive tubes which had previously been partially vacated. Many of the passages are only partially reamed out by the invading waters forced into the higher passages by the obstruction imposed on the system when Wesley Chapel gulf was formed through progressive collapse of the roof-rock over a more capacious, overwidened, mature section of its course. The chacteristics of the system immediately west of Wesley Chapel gulf, then, are special, and not necessarily typical or representative of the more matured sections of the underground system.

Waters rising from the deep pit in the floor of Wesley Chapel gulf enter the southern wing-like extension of the pit and disappear in the mud-covered talus rock along the wall at the southeast edge of the gulf. The rising waters of floods enter in greater and greater amounts and finally reach the cavern opening 30 feet above the low-water level. After washing over solid ledges of rock at the cavern opening, the waters descend southward over and through masses of tumbled and broken rock which nearly fill the cavern. The roof-rock of the cavern descends in about 100 feet to near the level of low water in the pool of the pit. Here the cavern turns southwesterly and west around the south end of the gulf. In the meantime large quantities of turbid flood waters pass through the two high-water channels in the alluvial floor of the gulf and descend through numerous swallow-holes into the explored underground system west of the gulf.

Entrance to the underground system is made through a small opening between the overhanging wall of the gulf and an inside talus slope

directly westward across from the rise-pit of Lost River. It leads directly downward to a nearly north-south stretch of underground Lost River 35 feet below. The massive rock at the level of the opening is the Lost River chert zone 20 feet above the base of the Ste. Genevive limestone formation. The cavernous routes of the underground system are in the St. Louis limestone which is locally characterized by numerous dark nodules and ball-like chert, especially some 15 to 25 feet below the top of the formation. The ball chert is well exhibited in many places in the underground system.

The north-south stretch of the underground channel just below the opening in the western wall of the gulf is about 325 feet in length. Northward it leads over a rugged floor above low-water level along the inside talus slope for about 100 feet to a broad, water-coursed, rock-floored passage which leads northwest nearly parallel with the western wall of the gulf for about 625 feet. During high-water periods it receives waters coming from the south over the rugged passage, waters coming through the talus rock just east of the beginning of the northwest course, and from two tubular passages which lead to the passage from the talus rock along the western edge of the gulf (Fig. 12). The tubular passages are a few feet above the low-water level of the main passage and at their debouchures rather deep plunge basins have been developed by the stormwaters entering from the gulf. During low-water periods these plunge basins are partially filled with soft, miring muds and cannot be waded safely. Opposite the entrance of the second tube, the waters of the main channel pass under the overhanging wall of the left side and part of them follow a distributary extending southwesterly as a low, wide passage for 210 feet to a breakdown in roof, beyond which it cannot be followed. The main passage to the northwest is 5 to 15 feet in height and 15 to 35 feet in width. The back part of it has much mud on the floor and on the large masses of rock which have fallen from the roof. Locally peculiar mud stalagmites are well developed on the mud surfaces (Malott and Shrock, 9, 55-60). The walls and ceiling are also thickly covered with muds, and the stalactites hanging from the roof are composed of alternate layers of mud and mineral calcite. At the end of the mapped route the waters pass into dissolved-out crevices where it appears that the rock masses from above have settled down without much disruption. A short distance back from the terminus, a passage leads upward 10 to 25 feet, or slightly more, to higher levels which terminate in two passages of broken down rock 150 and 295 feet back to the northwest. The muddy waters of flood periods have left watermarks as much as 35 feet above the floor of the main passage. Stalactites and flowstone above the watermarks are white and composed of pure calcite. A total of 1,440 feet of passageways were mapped in this section of the underground system. This section very probably connects with the unmapped section of the older and deeper system leading westward from Elrod cavern (Fig. 12).

A much larger and more complex section of underground Lost River is available in the passage leading southward from the entrance hole in the western wall of the gulf. A rather broad passage 15 to 30

feet in width and 5 to 15 feet in height leads almost directly southward for 215 feet to an abrupt westward turn (Fig. 12). Numerous small and several large passages debouch waters into the system from around the southern end of the gulf. In the first 65 feet the waters entering the passage flow northward, while in the next 150 feet the entering waters turn southward and proceed down the larger and more complex section of the system. A considerable part of the southward stretch is covered with accumulated muds and large masses of rock more or less cleanly washed. At the abrupt westward turn, 215 feet from the entrance, waters cover the entire floor and a well developed cavernous passage 12 to 30 feet in width and 7 to 15 feet in height leads away from the gulf in a generally western direction. Its cleanly washed floor is composed of rock. During low-water periods the waters of the passage may be waded easily except at the sharp turn 165 feet down the western passage. Here the water exceeds 5 feet in depth. The sides of the passage are rather rough with cherty masses and numerous solution scallops at or near water level. During high-water periods the passage is entirely filled with muddy stormwaters.

At the end of the water passage, briefly described above, the waters enter a low passage to the northwest in association with a network complex, depicted in Fig. 12, and described in detail in a former publication by the writer (7, 301-308). This remarkable network is developed at 3 levels, varying from 515 to 540 feet in altitude and 60 to 120 feet below the surface, all of which are entirely filled during flood periods. The network is developed chiefly along two intersecting joint sets in the St. Louis limestone, one nearly parallel with the dip of the formation (west-southwest) and the other nearly parallel with the strike of the formation (north-northwest). Some 200 feet west of the public road and about 1,000 feet west of the gulf entrance to the underground system, the main passages descend abruptly as much as 15 feet to ponded water passages in the lowest level of the explored section. The northern water-coursed passage descends noisily into crevices over rapids and a small waterfall which can be heard readily throughout much of the network system. The water-coursed passage follows a route 2,170 feet in length from the entrance hole in the gulf to the waterfall. The entire traversed network southward from the entrance aggregates a distance of nearly 5,000 feet in the system, though an airline distance to the most remote section reached is only 1,400 from the opening in the western wall of the gulf.

The network system above the descents to the lowest level is developed at two levels 5 to 10 feet apart, and in places the rock separating them has been removed. The upper level consists of tube-like passages which appear to have been developed from much smaller passages. The main and larger passages have been cut from the upper level into such sizes that they no longer show the original tube-like characteristics except by their network or anastomosing pattern. They are several feet above the low level and carry large volumes of water during floods. The complex system of water passages in the lower of the two levels, northwest and west from the disappearance of the flowing

waters from the main passage at the beginning of network system and thence on to the waterfalls to the northwest, has the appearance of being unfinished or young as an underground system. The waters passing through it play hide-and-seek through the low channels which were originally small tubes developed below the water table. The invasion of the river waters through the primitive tubes of the lower level is so recent that integration has not been completed. The waters follow the network rather than any selected passage through it. The network system is but little modified from its primitive condition as formed below the watertable by phreatic waters independent of the influx of surface waters which now course through the system.

In the remote part of the cavern passages beyond the abrupt descents to the lowest level explored in the system, the channel is quite mature and attains a width of 30 to 40 feet. It appears to be developed at the very level of the watertable at an altitude of about 515 feet. Waters stand in the broad passageway nearly to the ceiling, and it is impossible to follow it for any considerable distance beyond the abrupt descents into it. It appears to dip slightly westward and becomes permanently water filled all the remaining distance to the final resurgence of the underground stream south of Orangeville where it terminates at least 20 feet below the watertable.

Stormwater Resurgences along the Dry-bed

The winding course of the lower 11 miles of the dry-bed of Lost River has a relatively steep gradient, descending 85 feet to the Orangeville resurgence. The course is largely over a rocky floor, except in the last mile where both the bottom and sides of the channel are composed of alluvial silts and where pools of water are present during dry weather. The dry-bed becomes deeply intrenched below the sinkhole plain in the lower section of its course, and intermittent resurgences of stormwaters occur at several places along the route.

The first known stormwater resurgence or "wet-weather rise" along the dry-bed route is from pits and holes on the former Mathers farm in the SW of SW¼ of sec. 34, T. 3 N., R. 1 W, a little more than ¼ of a mile east of the dry-bed. The largest pit is 50-60 feet across and 20 feet deep. Its bottom is 540 feet above sea level. A mud-banked channel 15 to 20 feet in width leads away from it 12 to 15 feet above the bottom of the pit. The bottom of this large, cone-shaped pit is 45 feet below the swallow-holes in the dry-bed at the sharp westerly bend less than 1 mile to the southeast. The large resurgence pit is close to the north wall of a flat-floored, steep-sided gulch the head of which terminates abruptly nearby. Eight smaller intermittent resurgences were noted close to the channel leading away from the large one. All but one are on the north side (Fig. 13). Eastward from the steep-headed gulch several large, deep sinkholes descend abruptly below the upland plain. A row of sinkholes occurs in a broken-down strip leading southeast to the Peacher caves. These denote the decadent and nearly destroyed course of a high-level subterranean channel which once

probably conveyed Lost River waters in a short course from its dry-bed channel to the Mathers resurgence.

After heavy rains, large volumes of muddy stormwaters rise from the main pit of the Mathers resurgence and reach the dry-bed a short distance to the west. While some of these waters occasionally may come through an underground route from the swallow-holes in the dry-bed nearly 1 mile to the southeast, the chief sources of supply are from the sinkhole plain and its sinking streams northeast of this stormwater resurgence. A former surface tributary of Lost River heads about 3 miles east of Orleans and once passed through the town. It now terminates there, and after heavy rains overflows its terminal swallow-hole and floods much of the western part of the town (Fig. 14). Pearson

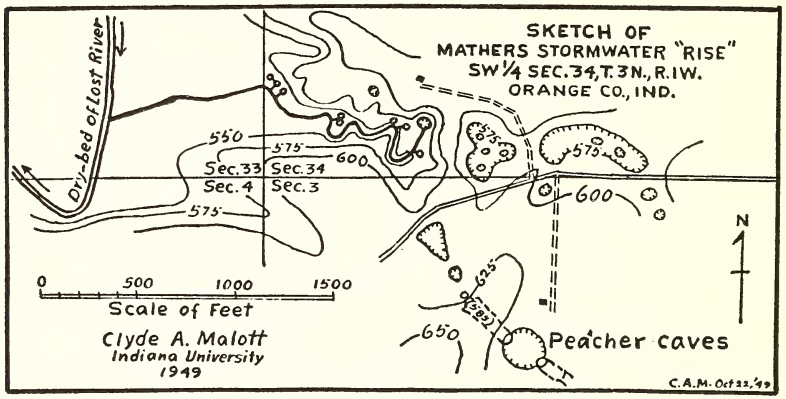

Fig. 13. Sketch of the Mathers stormwater resurgences near the partially intrenched section of the dry-bed course of Lost River, about 3½ miles west-southwest of Orleans. Large quantities of stormwaters issue from the pits here and flow into the nearby dry-bed. The waters probably come from sinking drainage northeast of the "wet-weather rises" and are not from the underground Lost River itself. The contour interval is 25 feet, and some of the deep sinkholes are shown nearby. The broken-down Peacher caves are indicated in the sketch.

Creek, heading southwest of Mitchell in Lawrence County, sinks in the southeast corner of sec. 15, T. 3 N., R. 1 W., though it occasionally overflows southward to the dry-bed. It is quite probable that its waters join with the underground stream coming from Orleans and the waters of the two streams furnish most of the stormwaters rising at the Mathers resurgence. The Mathers resurgence discharges stormwaters only. The watertable is considerably below the bottom of the rise-pit, and undoubtedly an underground stream of some size passes under or close to the pit. This underground stream carries all the normal waters and some of the stormwaters entering it, and only an excess of stormwaters rises to the surface and flows into the dry-bed nearby. The underground course of the stream passes on and probably joins underground Lost River about 2 miles southwest of the Mathers re-

Fig. 14. View of a flooded section of the town of Orleans near the terminal swallow-hole of "Old Sulphur", a former surface tributary of Lost River rising some 3 miles east of Orleans. The flooding waters frequently remain many days before retreating into the underground system which is 20 to 30 feet below the surface at Orleans. These waters probably in part return to the surface in the Mathers stormwater resurgences or "rises", 3½ miles west-southwest of Orleans.

surgence, though possibly it joins the underground stream which terminates at the Orangeville rise.

A group of 4 resurgence pits is present near the mouth of the karst valley 100 yards from the dry-bed in the SE of SW¼ of sec. 33, T. 3 N., R. 1 W., about ¾ of a mile west of the Mathers stormwater resurgence. Two of the pits are relatively large with a smaller one between them. The one on the north coalesces with another, and is faced on the north side by limestone. These pits are stormwater resurgences which empty large quantities of muddy stormwaters into the dry-bed following heavy rains. The waters very probably come principally from the karst valley heading near the center of sec. 21 and passing through the middle of sec. 28 and the eastern part of sec. 33. Minor amounts may come from the small karst valley to the northwest of the rises.

A little more than ¼ of a mile south, in the NE¼ of NW¼ of sec. 4, T. 2 N., R. 1 W., a stormwater resurgence of considerable size issues from an opening about 100 yards east of the dry-bed. It is more frequently used than the Mathers resurgence, being somewhat lower and closer to the dry-bed. The waters rising from it may come from the same underground stream, though their actual source is unknown. Several small holes were noted along the dry-bed along the western side of sec. 4, but it was not determined whether these holes are swallow-holes or resurgence pits. They have the appearance of swallow-holes.

The next resurgence is downstream in the more deeply intrenched section of Lost River valley about 330 yards south of the center of

sec. 8, T. 2 N., R. 1 W., (Fig. 2). Here the dry-bed is at an altitude of about 510 feet. The resurgence pit is relatively large and deep, and is connected with the dry-bed by a rising, mud-lined channel 200 feet in length and directed obliquely downstream. The resurgence pit itself appears to be a hole in the roof of a water-filled cavern or conduit of considerable size. In dry weather it contains clear water standing at a depth of about 10 feet below the dry-bed nearby. The water surface is a measure of the watertable here, and is only about 10 feet above the level of the water in the perennial resurgence pit of Lost River 1 mile to the west. During local rains this resurgence pit acts as a swallow-hole and conveys waters to the underground system before stormwaters from farther up underground Lost River arrive. Its location is rather significant. It is almost directly along the line of the underground course of Lost River and about half way between the underground channel at the Shirley or Wesley Chapel gulf and the perennial resurgence on the Allen farm ¾ of a mile south of Orangeville. Possibly it is an opening to the surface of the main water-filled underground course of Lost River itself, though it may be merely an opening in a subsidiary underground conduit connected with the main underground route.

In the compound deeply intrenched meanders southeast of Orangeville, at least 5 localities along the dry-bed have one or more pits which give out stormwaters after heavy rains. These localities are indicated on the map of the dry-bed (Fig. 2). The first of these consists of several small holes on the banks of the dry-bed, in the western loop about ⅜ of a mile west of the center of sec. 8. They appear to be relatively unimportant. Two large holes in bedrock, one in the dry-bed and the other 75 feet to the west, give forth relatively large quantities of stormwaters ⅜ of a mile north of the center of sec. 8. Clear waters stand in these holes about 10 feet below the dry-bed during dry periods. A cavernous opening facing downstream is present in the SW of SE of SW¼ of sec. 5, a little over ½ of a mile east of the Orangeville rise. It is located on the north bank of the rocky dry-bed. Standing waters reach the cavern ceiling about 12 feet below the surface. Apparently large quantities of stormwaters gush out of this opening after heavy rains. Possibly they come from the local karst valleys to the north and east, rather than from conduits connected with the underground course of Lost River. The small holes near the northeast corner of sec. 8 do not appear especially important. A short distance farther downstream, just above the bend to the west, in the SE of NE¼ of sec. 7, is an important stormwater resurgence pit connected with the dry-bed by a mud-lined channel 100 feet in length on the east side of the dry-bed. Some holes also are present in the dry-bed channel on the west side. Large quantities of stormwaters issue from this pit, and they continue to flow for some time after all the others upstream have ceased. Below this intermitten resurgence the dry-bed swings westward along the steep south bluff east of the bridge about ½ of a mile south of Orangeville. Apparently some small sinks are present at the base of the steep slope above the bridge, as waters do not stand in the deep pool here in dry periods. Downstream from the bridge waters stand in pools during dry

period, and occasionally stormwaters coming from the Orangeville resurgence flow upstream to beyond the bridge. This upstream flow is associated with the earlier appearance of stormwaters issuing from the Orangeville rise.

The Terminal Resurgences of Lost River

The entrance of the waters from the Orangeville resurgence brings the dry-bed channel of Lost River to an end. The Orangeville rise issues from a semicircular rock-walled pit 110 feet across, and the waters rising from it flow southward in a mud-banked channel 15 feet deep and 40 to 50 feet in width for about 150 yards before entering Lost River. The waters rise some 15 or 20 feet as a great artesian spring from a water-filled cavern the mouth of which is apparently 70 feet in width. The rock wall above the waters is composed of even-lying beds of the lower part of the Ste. Genevieve limestone about 30 feet above the St.

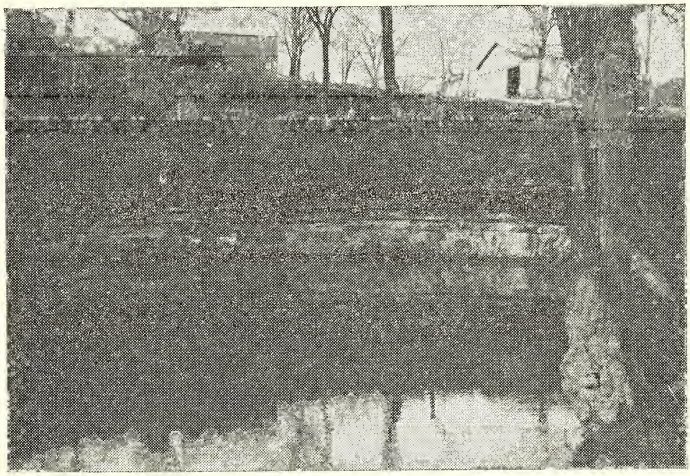

Fig. 15. View of the Orangeville resurgence or "rise" in the deeply intrenched section of Lost River. The entrance of these waters into Lost River marks the terminus of the dry-bed. The waters come from karst valleys to the north and northeast of Orangeville and form an important tributary to Lost River. The perennial "rise" of Lost River itself is along the stream three-quarters of a mile to the south.

Louis limestone. These layers form an overhanging, lunar-shaped cliff about 15 feet above the waters in the rise-pit. The Orangeville rise is quite impressive, and is regarded by many local people as the rise of Lost River itself (Fig. 15). It never goes dry, though in dry weather its flow is reduced to only a few cubic feet per second. After heavy rains its flow is estimated to reach or exceed 2,000 cubic feet per second, and its lunar-shaped, low cliff is submerged and the channel leading to Lost River is filled to overflowing.

The Orangeville resurgence is the terminal orifice of the drainage of several karst valleys to the north and northeast, comprehending 30 square miles or more of rugged terrain composed of sandstone ridges and limestone-floored valleys. As much as 10 or 15 square miles of this drainage comes from numerous sinks and swallow-holes in the Beaver Creek drainage along the B. & O. Railway in Lawrence County 6 miles north of the Orangeville rise (Fig. 1). The whole of the upper part of Beaver Creek drainage is much dismembered, losing it drainage to White River on the north and Lost River on the south through at least 150 separate swallow-holes. One considerable stream enters a swallow-hole 50 feet below the old and nearly destroyed alluviated floor of Beaver Creek valley ½ of a mile west of the old village site of Georgia. The low cavern beneath extends slightly east of due south, though it was not traversed beyond a distance of 250 feet from the swallow-hole. Apparently its deep underground route passes beneath the high sandstone divide between the Beaver Creek and Lost River systems. The waters enter the swallow-hole at an altitude of 610 feet and reappear at the Orangeville resurgence at an altitude of 495 feet, having a fall of 115 feet in the 6 miles of the underground route. Several caverns in the karst valleys north and northeast of Orangeville are local stormwater routes which connect with the underground system. Among these caverns are Salts cave, in the NW of NW of sec. 18, T. 3 N., R. 1 W., in Lawrence County; Black Man cave, in the SE of NW¼ of sec. 19; Showfarm cave, in the SE of NE of NW¼ of sec. 25; and Maple Grove cave, in the NW of NW¼ of sec. 22 (Fig. 1). In addition to the karst valley area north of Orangeville, it is quite possible that the waters which come from "Old Sulphur" at Orleans and from sinking Pearson Creek southwest of Mitchell, except for the intermittent stormwaters issuing into the dry-bed at the Mathers stormwater resurgence and others, also join the underground system and issue at the Orangeville resurgence.

In the karst valley about ½ of a mile north of the Orangeville resurgence a considerable gulf has developed through collapse over the underground stream. It has been called the Orangeville or Ragsdale gulf (Malott, 7, 290-291; Childs, 1, 84-97). It is approximately 600 feet in length and 300 feet or more in width. It has a steep perimeter on the north end which rises 30 to 50 feet above the pits in the irregularly alluviated floor. After very heavy rains it fills to a maximum depth of 30 or 35 feet and overflows to the southeast, but it contains no running waters during dry weather. A short distance north of the gulf, in the NE of NE¼ of sec. 6 (Fig. 2), two swallow-holes receive surface stormwaters in considerable quantities along Dry Branch, but when the underground channel becomes filled beyond its capacity, stormwaters reverse rather suddenly and issue from these holes, turning them into rise-pits. Large quantities of stormwaters issue from the deeper of the two holes and keep waters running in Dry Branch for some time after heavy rains.

The perennial and principal resurgence or rise of Lost River is a deep, mud-lined pit in low ground just east of Lost River on the Allen

farm a short distance south of the center of sec. 7, T. 2 N., R. 1 W., about ¾ of a mile south and a little west of the Orangeville resurgence. This large pit is grown about by bushes and trees and its steep muddy banks make it difficult to approach. Soundings in it during a low-water period indicated a maximum depth of 17 feet, though its actual water-filled cavernous route from the east may be somewhat deeper. It is so close to the Lost River channel that it joins it almost directly. During dry weather the deep, clear waters issuing from it scarcely show any movement, but its muddy stormwaters "boil" up vigorously from the terminal underground route of Lost River and flow away in rapid movement. After heavy rains the steep muddy pit is filled to overflowing and close approach to it is difficult and perhaps unsafe. It presents a rather forbidding appearance, even in dry weather. It has none of the beauty of the easily accessible and frequently visited cliffed-pit of the Orangeville rise.

It is remarkable that all of the gathered bedrock seepage and phreatic clear waters of the underground Lost River system should have only two outlet orifices, with the one on the Allen farm returning to the surface all the clear waters entering at the sinks of Lost River more than 7 miles away and the lithic and phreatic waters gathered along its lengthy underground course. The low-water courses of the two systems are, indeed, well co-ordinated, ending each in its own single terminal resurgence. In flood, the two systems retain the two spectacular terminal orifices, but in addition have others only slightly less impressive. In times of floods the capacity to carry waters beneath the surface and the ramification of the systems are more fully comprehended when the great volumes of intake waters from diverse and widely separated areas are considered in conjunction with the many resurgences then in operation.

Summary and Conclusions

Lost River sinks in its channel during dry weather at or near the local watertable at an altitude of 620 feet. The same waters return to the surface from an underground route more than 7 miles to the west where the lower part of the stream system and the watertable is at an altitude of 490 feet. The main underground course appears to be relatively directly westward and follows close along the watertable level beneath the sinkhole plain and considerably below the course of the tortuous dry-bed channel which is followed only by the excessive stormwaters gathered from some 47 square miles of the upper part of the stream system. The dry-bed course is at least 22.5 miles in length and is without tributaries. Its upper section is characterized by numerous small and several large intaking stormwater swallow-holes. The lower section of the dry-bed course is relatively deeply intrenched, but still above the westerly descending watertable. It receives considerable amounts of the underground stormwaters which issue as intermittent resurgences at higher levels than the final and continuous resurgence of underground Lost River. Some of these intermittent resurgences come from the sinking stormwaters of certain former sur-

face tributaries which now fail to reach the dry-bed course, while some come from the flooded underground cavernous course of Lost River itself.

Lost River is the largest stream in the karst region of southern Indiana which does not have a continuous open course along the level of the watertable. East Fork of White River to the north and Blue River and Indian Creek to the south arise beyond the limestone sinkhole plain developed on the St. Louis and Ste. Genevieve limestones and follow deeply intrenched courses which determine the watertable levels of the areas through which they pass. Lost River had such an indirect course across the limestone upland that it was not able to intrench its course below the upland plain except downstream from the western margin. Consequently, the upper part of the drainage system and its dry-bed section are perched on the limestone upland. The lower course of Lost River, however, is deeply intrenched and is at local baselevel. Here the stream sets the limits of the watertable level.

The westerly dip of the limestone beds combined with the well developed joint system facilitated the withdrawal of the watertable to lower levels than the perched stream system in a large area of the upper part of Lost River basin. This withdrawal of the watertable was accompanied by the development of multitudinous downward solution-formed openings which conveyed surface waters derived from rainfall to lower levels. The downward dissolved-out leads are wide-spread, and most of them mark the sites of tens of thousands of sinkholes which have become surface hoppers feeding rainfall waters to underground routes. The withdrawal of the watertable below the upland surface first took place closely adjacent to the intrenched lower course of Lost River and sinkholes and sinking drainage were first developed along the western margin of the upland limestone plain. Later the lowering of the watertable proceeded farther east and farther up the course of the present dry-bed. Thus, the sinkholes of the upland limestone plain and the swallow-holes of the sinking streams were developed farther and farther from the resurgences of the waters in the intrenched section of Lost River. The present sinks of Lost River are relatively young and are developed but slightly above the present watertable. The sinkhole plain itself is developed some 2 miles farther east than the sinking stream and several square miles of the former surface drainage now descend into sinkholes and the underground system independent of the surface stream. Thus, of the 53 square miles of Lost River drainage above the sinks, only 47 square miles of actual surface drainage are directed into the underground system at the sinks and in the storm-water swallow-holes of the dry-bed.

It is interesting to note that the entire surface drainage of Lost River above the sinks is completely surrounded by sinkhole topography and underground drainage: It is an island-like area in the midst of a great karst plain. It is a surviving surface drainage on a potentially soluble limestone upland remote from the intrenched drainage which set the condition under which subterranean drainage could develop all about it. It offers an example of surface drainage on a readily soluble

limestone upland refuting the conception of deepseated phreatic drainage independent of a lowered watertable.

The development of the underground drainage of the perched sinkhole plain with its sinking streams is definitely associated with rainborn waters which fell upon the surface areas of the system. Certainly it cannot be gainsaid that the thousands of sinkholes which characterize the topography of the areas with a lowered watertable have resulted from the rain waters which fell upon them. They are surface solution sinkholes and have no other supply of waters than rainfalls. The freshly fallen acidulous waters are potent consumers of limestone beneath the soil surface and enormous quantities of rock have been removed over large areas of the general surface and clearly manifested in the deepened sinkhole voids where the watertable is considerably below the upland surface. In areas where the watertable is close to the surface the sinkholes are shallow and pass eastward into

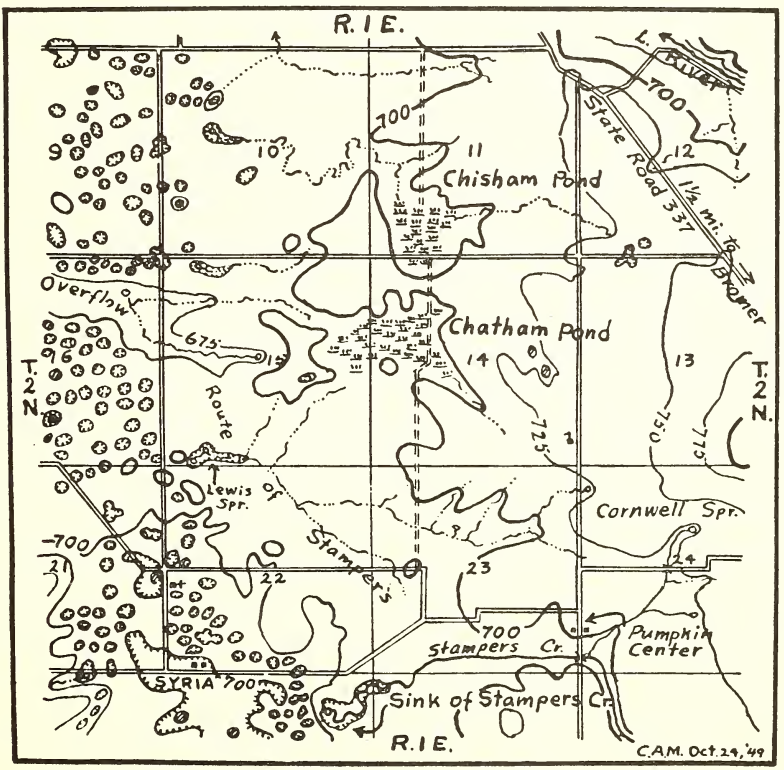

Fig. 16. Topographic sketch showing surface drainage with a high watertable passing westerly into sinking drainage and sinkhole topography with a lowered or withdrawn watertable. Chisham and Chatham ponds are karst fens or swamps in slightly developed solution pans at or near the watertable. The locality of the sketch is south of Lost River 3 to 7 miles southeast of Orleans and southeast of the sinks of Lost River.

barely discernible solution pans and thence into areas of surface drainage. This condition is clearly manifested in the drainage and topography in a strip of terrain some 2 miles in width extending southward along the eastern edge of the sinkhole plain some 2 or 3 miles east of Orleans and west of Leipsic, where surface drainage on the upland passes westward into well developed sinkhole topography. Here also the water table passes from one barely below the surface of the flat upland to one which is withdrawn to considerable depths beneath. The small sinking streams at first discharge into broad, shallow solution pans or into karst fens or swampy ponded areas, such as the drainage westward from "The Flatwoods" just west of Leipsic, or in the localities of the Chisham and Chatham ponds in sections 11 and 14, T. 2 N., R. 1 E. (See Figs. 1 and 16.) Stampers Creek itself sinks into a similar shallow area in the same strip of terrain in the NE of NE¼ of sec. 27, some 2 miles south of the Chisham and Chatham ponds.

If the sinking of rainfall waters on the general upland limestone plain made the sinkholes and the vertical leads which descend to the watertable, it follows that these same waters were directed into the permissive bedding planes down the dip of the beds at or near the westerly descending watertable and dissolved out small tubular routes which lead out from under the lands upon which the waters fell. These small dissolved out routes are multitudinous and of such sufficiency that underground drainage in the sinkhole plain is 100 percent complete. Some of these small watertable leads received quantities of acidulous surface waters from incoming streams and in time were developed to such dimensions that they could carry all of the waters fed to them from the surface streams. Those receiving the waters of surface streams of considerable size have been developed into great cavernous routes of underground drainage through which gathered stormwaters go. Among them is the underground system of Lost River itself. Lost River pours much of rainfall gathered from 47 square miles of surface area into its underground system. These waters enter through the sinks and the various stormwater swallow-holes along its dry-bed channel. The amounts of stormwaters carried by this underground system bear convincing testimony of the size of the underground system and of the efficiency of these waters to develop their own routes beneath the limestone terrain. Waters derived from the surface constitute the agency through which areas have become an extensive sinkhole plain and by means of which great cavernous routes extend for miles beneath a pitted plain whose upland surface acts as a regional sieve to absorb the rainfall and the gathered waters from sinking surface streams. The region furnishes an excellent and convincing example of caverns developed through the invasion of potent acidulous surface waters to underground routes which were originally tiny and little developed.

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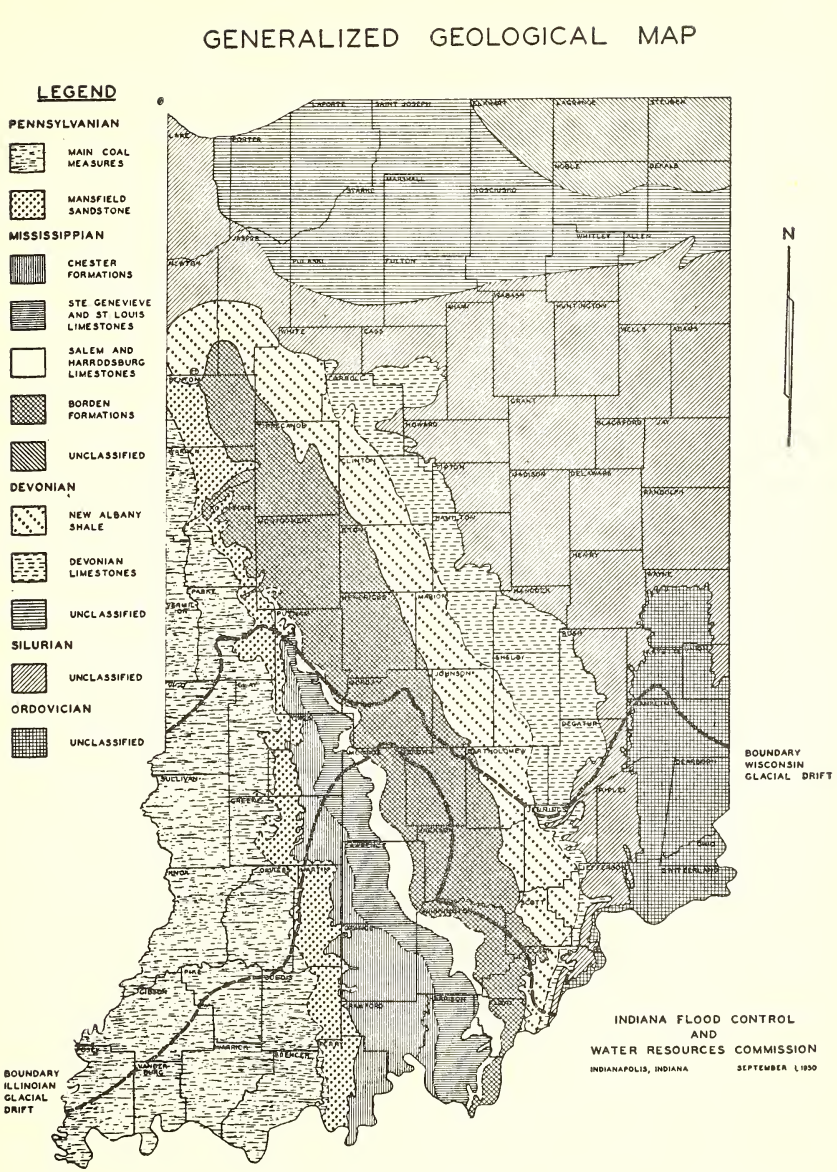
Some Applications of Geology to the Location of Dam Sites in Indiana

Preston McGrain, Lexington, Kentucky

The greatly increased interest and activity in collecting and controlling surface waters by impounding for flood control, water supply, hydroelectric development, and recreational purposes has made geology an increasingly important factor in engineering work in Indiana. The purpose of this report is to describe some of the general and specific geologic conditions in Indiana which will affect the economics, effectiveness, and safety of dam sites. The observations incorporated herein are primarily those made by the writer while on the technical staff of the Indiana Flood Control and Water Resources Commission from 1947 to 1950. Over fifty suggested sites and numerous completed sites were observed and studied during this period. Reports covering many of these investigations are in the files of the Indiana Flood Control and Water Resources Commission in Indianapolis.

Numerous requisites for a satisfactory reservoir have been set forth by various writers. Very few dam sites in Indiana are ideal from strictly a geologic point of view. All rock at the surface has been attacked by the various weathering agencies, and this weathering has not affected the rocks uniformily. Joints, bedding planes, and miscellaneous fractures are to be found in the rock. Solution openings occur in carbonate rocks and may extend for considerable distances. Porous sands and gravels are common in unconsolidated deposits. The geologist, therefore, is primarily concerned with determining the tightness of the retaining basin, the foundation of the dam and associated structures, available materials of which to construct the dam, and amount and character of materials which will be deposited by streams flowing into the reservoir. The identification of earth materials at the site of a proposed dam and reservoir is one of the simplest tasks of a geologist assigned to a project. On the other hand, the geologist has a very responsible job when it comes to the correct interpretation of the results obtained.

The geologist is not concerned with the methods by which the dam is constructed, except in relation to the local geological conditions, but is primarily interested in the load that the dam will form and the depth to which it is to be constructed in order to stop possible leakage. The most common type of dam site in Indiana lies in a narrow part of a valley where the rock of the abutments of the site is more or less visible, but in the bottom of the valley bedrock is hidden by alluvium and outwash. The first problem for the geologist is to determine the depth to bedrock in the valley. If the stream is aggrading the depth of alluvial fill may be very great, whereas if the stream is still degrading its bed the alluvium over which it runs is probably very thin. Limestones and sandstones found in Indiana should be sufficiently competent to support a dam. On the other hand, many shales and clays may not be able to



ADAPTED FROM GEOLOGICAL MAP OF INDIANA. INDIANA DEPARTMENT OF CONSERVATION. DIVISION OF GEOLOGY. PUBLICATION NO. 112. 1932.

FIGURE 1

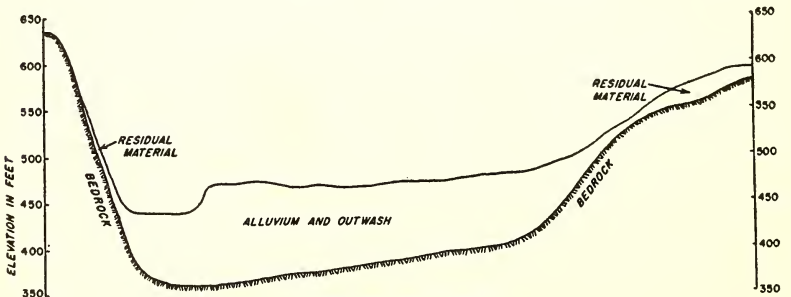
resist the load of man-made structures imposed upon them or their equilibrium might be disturbed if overlying material are removed. Examples of such disturbances have been observed along some of the highways within the state and it is not unreasonable to expect a repetition of this phenomena at dam sites if care isn't exercised in the selection of the site.

Requirements concerning leakage for dams vary according to the use intended for the resulting reservoir and the effect upon the dam itself. Leakage should not be serious where the impounding rocks are sandstone, shale, siltstone, or till. Where limestones, sands, and gravels are present serious leakage may occur. The seriousness of this leakage is due not only to the occurrence of voids in these latter earth materials but also because such openings might enlarge under the increased pressure due to impounding of water in the reservoir.

Since some method must be provided by which excess waters may pass a dam, the geologist is concerned with the erosive effect of the earth materials in and along the spillway site and the route of the spillway waters.

Approximately five-sixths of the total area of Indiana has been subjected to glaciation (Figure 1). Consequently, glacial deposits, including both glacial drift and glacial outwash, are the most common earth materials encountered along Indiana's streams.

Since the heterogenity of glacial materials and the complexity of their arrangement are well known many geologic conditions enter into engineering problems for dam and reservoir sites in glaciated areas. In addition to avoiding glacial deposits containing bodies of porous sand and gravel, the problems of providing a foundation for a dam and an opportunity for building a safe and ample spillway to dispose of surplus water are also important requisites. Ordinarily, glacial till can be expected to support an earth and rock filled dam. On the other hand, because glacial materials are generally unconsolidated, spillways must be lined with concrete, which necessarily adds to the expense of the installation.



GENERALIZED CROSS SECTION
OF
EAST FORK OF WHITE RIVER VALLEY
NEAR SHOALS, INDIANA
ADAPTED FROM U.S. CORPS OF ENGINEERS DATA

FIGURE 2

Streams in or adjacent to glaciated areas often carried glacial meltwaters and glacial debris. Many such streams are filled to a great depth with unconsolidated deposits. Lower Wabash River, both forks of White River (Figure 2), both forks of Whitewater River, and numerous smaller streams are examples. Opportunities for leakage under and around a dam constructed across such a valley probably would be great. The installation of costly cores of impervious materials would be necessary to prevent the loss of water and damage to the dam itself. However, with everything else being satisfactory these latter valleys could be used for dry dams for flood control purposes similar to those in the Miami Valley of Ohio.

Many of the streams in the glaciated area are young, geologically speaking. Their valleys are frequently narrow and shallow. Consequently, their capacities for storing waters are quite limited. This factor must be taken into consideration when planning a reservoir for flood control or water supply purposes.

The effects of glaciation are further noticed because of derangments and modifications of drainage systems which existed prior to the advance of the ice sheets. In the region of Wisconsin glaciation drainage lines have been developed in a thick blanket of glacial drift which was deposited over an irregular and eroded bedrock surface. Preglacial and interglacial bedrock valleys are present, though usually hidden from view. Great streams, like Wabash, Mississinewa, Salamonie, Eel, Tippecanoe, Iroquois, and many others intermittently encounter bedrock and glacial drift at many places along their routes (3). Usually at the places where a stream encounters bedrock narrow outlets occur which require

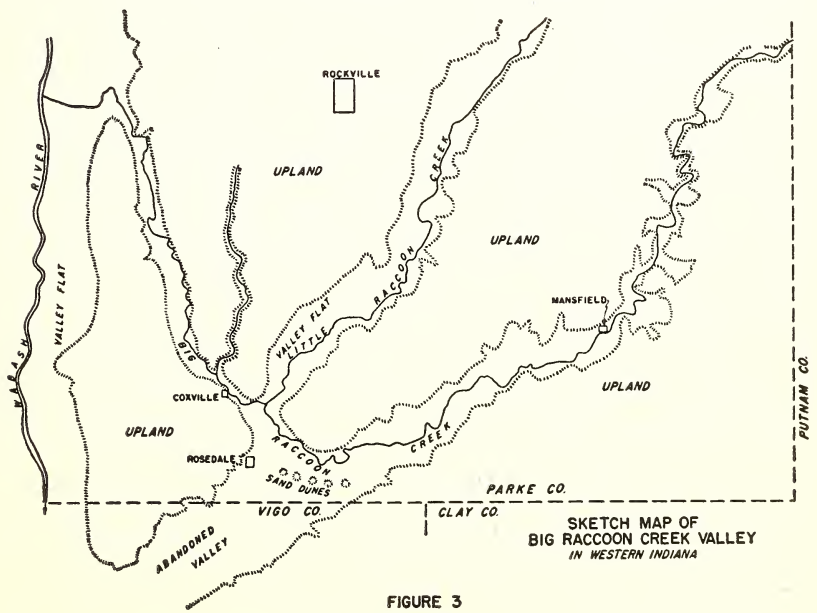
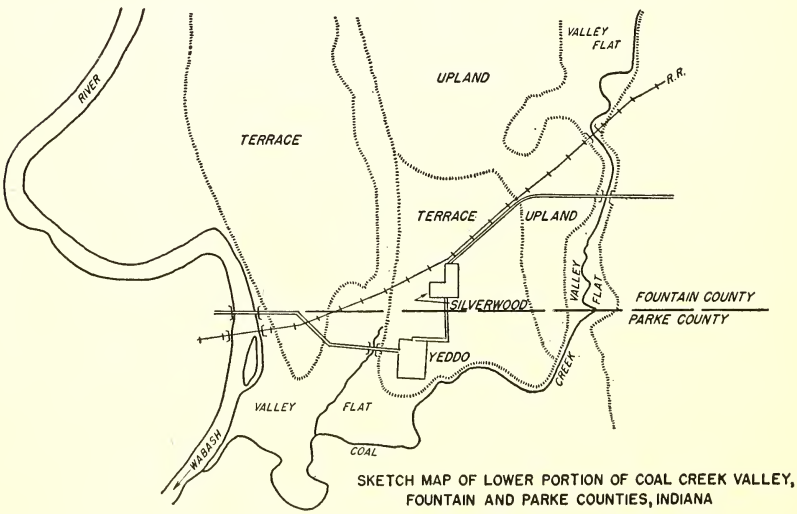


FIGURE 3

relatively small and economical dams, with foundations able to sustain the structure. However, at relatively short distances away it is just as common to find glacial materials at low levels because of the low elevation of the dissected bedrock surface. It is the geologist's responsibility to determine the character and extent of such sediments and whether or not impounded waters can be retained in the proposed basin. To avoid leakage of water from the basin of the reservoir the reservoir either must be lined or located at such a place that leakage into the ground is resisted by natural conditions. Inasmuch as the cost of lining a large reservoir is prohibitive, the latter qualification is a prime requisite. Unless the dam and the adjoining rocks are impervious to water serious leakage may occur.

There are numerous examples in Indiana of deranged drainage lines which appear to offer excellent opportunities for impounding surface waters. Big Raccoon Creek (Figure 3) is one of the most striking examples. The course of this stream was altered during or just after glacial times. From its junction with the Wabash River upstream to Rosedale the stream occupies a deep and relatively narrow valley which was tributary to its preglacial ancestor. At Coxville the constricted valley is associated with a thick deposit of sandstone, overlying Coal III and partly digging below it for a short distance. Immediately upstream from Rosedale the valley widens suddenly and spectacularly where it meets a valley which was a discharge route of glacial meltwaters. The drainage divide at this point is barely forty feet above the flood plain of the stream. It would be possible to locate a dam in the vicinity of Coxville, but a long, high dike or levee would be required to cross the low point in order to impound water in Big Raccoon Creek valley here. Other constrictions in Big Raccoon Creek valley occur near



SKETCH MAP OF LOWER PORTION OF COAL CREEK VALLEY, FOUNTAIN AND PARKE COUNTIES, INDIANA

FIGURE 4

Mansfield. However, a buried valley, which represents part of the former route of Big Raccoon Creek, is present. Although this valley has not been traced in detail, it is known to contain a quantity of sand and gravel.

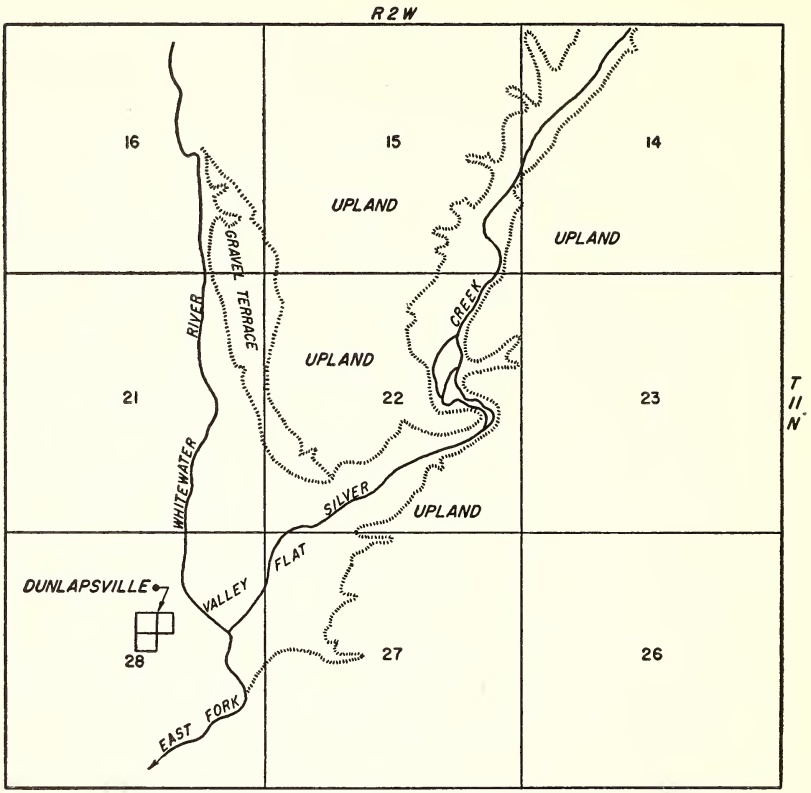
The character of the valley of Coal Creek near Silverwood also is unusual (Figure 4). The stream flows through a narrow rock-walled valley a short distance east of Silverwood, but immediately upstream the valley widens many times. The shape of the valley is made even more unusual by the rectangular cul-de-sac which extends in a southwesterly direction. This anomaly has been carved out of soft sands and undoubtedly marks a former route of Coal Creek. Test holes for coal immediately north of Silverwood have revealed an extension of this valley and confirm its significance.

The situation on the lower part of Silver Creek valley, a tributary of East Fork of Whitewater River in Union County, is not greatly unlike that described on Coal Creek. Silver Creek is a relatively short stream but occupies a rather broad valley. This stream even assumes braided characteristics as it nears the junction with East Fork of Whitewater River (Figure 5). About one and one-fourth miles upstream from this confluence the stream encounters a bedrock ridge of Upper Ordovician strata. The valley narrows abruptly as it crosses the ridge and then widens again just a few hundred yards down stream. Gravels from one-eighth to one-fourth inch in diameter were observed at the base of the little neck, or spur, of land near its junction with the upland mass between Silver Creek and East Fork of Whitewater River. Records of borings made for the Indiana Department of Conservation confirm the presence of a sand and gravel filled valley across this long, narrow spur which is only about 700 feet wide at its narrowest part.

Conditions similar to those described on the valleys of Big Raccoon, Coal, and Silver Creeks occur on Bean Blossom Creek near its junction with West Fork of White River. Bean Blossom Creek crosses a bedrock ridge at Mt. Tabor, in western Monroe County, through a narrow valley. Immediately upstream and down stream from this site the valley widens abruptly, suggesting modification of this drainage system due to glaciation. It has been reported by Mr. L. R. Gray of Gosport, Indiana, that a water well in the southwest quarter of section 3, T. 10 N., R 2 W., was drilled 207 feet deep without encountering bedrock. The entire section consisted of sand and blue mud. The deep hollows to the west and southwest also contain fine sand and clay. Thus, it would appear that the preglacial valley of Bean Blossom Creek lies immediately north of its present channel at Mt. Tabor.

The conditions in Mill Creek valley in Owen and Putnam Counties, which were described by the writer (2) at an earlier date, are also similar to the streams and valleys just described.

The possible hazards which accompany the location of a dam site in a limestone terrain have long been recognized. In Putnam, Owen, Monroe, Lawrence, Greene, Orange, Washington, Harrison and Crawford counties, Indiana, there is an area of approximately 2000 square miles with limestone at or near the surface. According to the late Dr. C. A.



SKETCH MAP OF PORTION OF SILVER CREEK VALLEY
IN
UNION COUNTY INDIANA

FIGURE 5

Malott[1] 680 square miles are wholly characterized by sinkholes and 100 percent underground drainage, 350 square miles are karst valley areas, while 750 square miles are characterized by occasional to numerous sinkholes and partial underground drainage. There are also 150 square miles in Jennings, Jefferson and Clark Counties, Indiana, characterized by sinkholes, some swallowed drainage, and occasional caverns.

The Middle Mississippian limestones, particularly the St. Louis and Ste. Genevieve formations, are notoriously cavernous and are generally considered risky as retainers for impounded waters. However, karst features are common in other Mississippian formations. Only the thin Rockford, Floyds Knob, Reelsville, Vienna, and Clore limestones of the Mississippian limestone formations are without conspicuous solution

[1] Personal communication, 1950.

features. Masses of limestone in the form of bioherms are present occasionally in the Borden Group, a series of formations generally considered as among the most impervious and impermeable rocks in Indiana. Such a limestone deposit exists in the narrow ridge between Salt and Allens Creeks in southeastern Monroe County. This limestone is well jointed and contains a small cavernous opening. A reservoir located at this point might be subject to serious leakage unless the height of the dam were restricted.

Several streams, including Indian creek in Lawrence and Martin Counties, Lost River, Blue River, and Big Indian Creek in Harrison County, flow long distances across these limestone terrains. Swallow holes, subterranean cut-offs, springs, caverns, and other features evidencing movement of ground waters and solution work abound along these streams and their tributaries offering warnings of unsatisfactory conditions for extensive impounding of surface waters. Low dams with small reservoirs in limestone areas can frequently be successful retainers for small local water supplies because of the alluvial and residual clays which usually cover the valley floor and flood plain.

Caverns and sinkholes are also common in Devonian and Silurian limestone formations, particularly the Jeffersonville limestone, along the upper part of Muscatatuck River and its tributaries. Meek Cave, located six miles southwest of North Vernon, is an example.

No attempt will be made here to describe the multitude of conditions found along all of Indiana's streams. Such is not the purpose of this report. Rather an attempt has been made to point out certain types of problems which are present and the outstanding features which characterize them. Dams and reservoirs in Indiana have been or will be constructed under a variety of geological conditions. No two sites will be alike. Each site must be studied and analyzed individually, keeping in mind the purpose desired and the limitations imposed thereon. Consequently, geology will continue to be an important factor in engineering. Dams for water supply, flood control, and hydroelectric power are desirable and necessary for the development of Indiana. By proper application of geologic data to sound engineering practices not only can many costly construction problems be avoided, but also chances of disastrous dam failures, such as the classical example of the St. Francis Dam in California in 1928 (1), can be in a large part prevented.

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An Illustration of Mapping as Applied to Locating Retail Stores in a Metropolitan Area

Jack C. Ransome, Indiana University

Statistics of the United States Department of Commerce show a considerable mortality of small retail businesses in metropolitan areas. Recent field research in the Boston, Massachusetts, area has not only revealed numerous failures of retail units within the first year of operation, but indicated that some locations have experienced repeated failures.

The failure of retail units to continue in business for a profitable period of time is partly the result of an ignorance of urban patterns. Such patterns include the distribution of population, the network of transportation, the density of pedestrian and vehicular movement, and the location and character of retail shopping centers. These patterns change rapidly.

One factor of urban change is the fast growth of population which produces shifts in density. Movements of people away from the urban core and toward the fringe of the city have caused the relative or absolute decline of some business sectors and shopping centers and the rise of others.

Furthermore, the changing economic base of some cities and the increasing vigor of city and regional planning have accelerated modifications of patterns as reflected in the construction of arterial highways, establishment of mass housing projects, plotting of new industrial sites, and re-zoning. The prospective merchant must anticipate and study these developments and their effects wherever possible before his store is committed to an urban or suburban location and a physical site.

Urban patterns are most clearly and easily discerned on maps. A series of maps of the Boston metropolitan area, prepared at the Institute of Geographical Exploration, Harvard University, illustrates several ways in which maps may assist in the general location of retail units. First, a base map on a scale of one inch to three-quarters of a mile was prepared, which brought the street mapping of the Boston metropolitan area up to date.

Second, a population distribution map was prepared to give a picture of the areas of most dense population, and, consequently, the larger retail markets. Data derived from census tracts and by field reconnaissance were plotted by dots on the base map. Each dot represented 100 persons. No attempt was made on the dot map to distinguish any particular period or recency of growth, although this information was available from field maps. Field data showed a distinct westerly and southwesterly trend of population growth in the Boston area. Such growth tends to be oriented along and perpendicular to major arteries

which focus on the hub of Boston. Out-migration toward dormitory towns on the perphery has spurred the development of new shopping centers while Boston proper has suffered a severe decrease in its taxable base.

The final maps of the Harvard series presents the distribution of retail shopping centers of Boston overlaid on the population pattern of the metropolitan area. A shopping center on this map is defined as one which has at least five retail units. It may occur as a cluster at or near an intersection, or as a string or linear development along a well-traveled street.

Each of the clusters was mapped in the field at ground floor level. A size classification was established on the basis of the total number of retail units in the cluster, and the number of specialty shops, such as hardware, hosiery, hats, jewelry, etc. The classification covered all magnitudes of retail shopping centers from the small local service groups to the great agglomerations of specialized stores.

It is clear from an analysis of the pattern of shopping centers that as the magnitude of the cluster increases the specialization of retail functions increases. Clusters of similar magnitude have functions which are similar. The specialization of the function occurs even in areas of low income groups, although individual stores in such areas probably reflect a lower investment of capital and a poorer selection of goods.

Thus, from the maps in the Boston project, and from supplementary maps and data, a researcher could gauge the general movement of population along arteries, select a growing retail center, and suggest what types of retail units could be added feasibly to this center. By studying the proximity and magnitude of centers as they were mapped, the researcher could obtain a rough estimate of the trade territory of each center, and could further define the business potential by mapping the density of pedestrians and vehicles in any given cluster. More refined mapping will suggest the best physical sites for a particular retail unit within an existing or developing shopping center.

It is realized that large scale mapping projects are normally beyond the means of individual merchants, but sketch maps of likely locations may be made quickly to be proved later by population and traffic density maps and data from public agencies such as planning commissions. Decisions as to location of retail stores must be made quickly but accurately. It is significant that one super-market chain in the Boston area is plotting store locations in anticipation of highway construction and suburban housing development to the extent of very large purchases of property. The chain relies on its understanding of changes in urban patterns.

While the data and maps presented here are based on Boston, it is likely that the techniques discussed are generally applicable to cities such as Indianapolis, other metropolitan centers, and smaller cities. Mapping can lead toward a more scientific and a more secure location of retail units in all areas.

Short Line Railroads of Indiana

Willert Rhynsburger, Indiana University

During and since the war, impressive changes have taken place in the transportation system of the United States and of Indiana. New pipeline movements, the inception of long hauls of bulky commodities by motor truck, recently accelerated use of air freight, and the conception, at least, of conveyor belts as long-distance common carriers, suggest the emergence of a new era in inland transportation. As a result of evolutionary developments such as these, the relative importance of railways as agents of regional circulation has declined, although the actual volume of freight carried rose steadily between 1946 and 1951. This absolute traffic increment has served, at least for the present, to retard the rate of railway abandonment and other reductions in service.

Among the hardiest elements of the railway pattern in their resistance to curtailment, are the short lines. Despite the inroads of competition, absorption, and obsolescence, eight short line railroads, exclusive of switching and terminal roads, continue to function in the Indiana transportation establishment. These small railways range from two to forty-two miles in length. Three of the lines are located in the northern part of Indiana, one serves the central part of the state, and four are in the far south. Beyond their interest as unique elements in a vastly changing transportation system, these lines pose the geographic problem of assessing their role within the system.

Although there is overlapping of functions, three categories of services are performed by the Indiana short lines: (1) three of the lines link urban centers with by-passing main line railroads; (2) three others connect specific industries with by-passing main lines; (3) the two remaining roads, which also are the longest lines, perform general freight service for various communities and industries along their tracks.

The three Indiana cities which are in part linked to the outside world by short-line connections are South Bend, Corydon, and Ferdinand. From South Bend, the New Jersey, Indiana, and Illinois Railroad extends southward for eleven miles to a junction with the main Chicago-Toledo line of the Wabash Railroad at Pine. The name of this connecting road, which was built by the Singer Sewing Machine Company, refers to the location of that firm's headquarters in Elizabeth, New Jersey. The chief purpose of the line was to relieve the company's South Bend cabinet works from dependence upon the New York Central for freight movements. Although control of the line subsequently was transferred to the Wabash Railroad, it continues to be operated under the "New Jersey" name.

Unlike South Bend, where the N. J. I & I. is only one of several diverging railways, the communities of Corydon and Ferdinand are

each served by a solitary rail connection. The Louisville, New Albany, and Corydon Railroad extends from Corydon 7.7 miles north to the Southern Railway's Louisville-St. Louis line at Corydon Junction, 17 miles west of New Albany. Principal freight movement is inbound to Corydon, shipments consisting chiefly of coal, petroleum products, and less-than-carload freight. Grain is handled outbound. Service totals one round-trip daily, and the road's solidarity is attested by the recent installation of a new diesel locomotive.

The Ferdinand Railroad forms the link between Ferdinand, in southern Dubois County, and the Southern Railway at Huntingburg, 7.4 miles distant. Using as motive power a steam locomotive purchased from the L. N. A. & C. RR., the Ferdinand Railroad operates two round-trips daily. In addition to the usual coal, grain, and less-than-carload movement, the Ferdinand carries in particular the traffic of the local furniture plant. This short line forms an interesting example of municipal enterprise. Built during an era in which it was felt that the existence of a railway connection would assure the industrial stature of any community, the Ferdinand Railroad has been sustained chiefly through the loyalty of local citizens.

The second class of Indiana short lines embraces those which connect industrial establishments with nearby main lines. Two of these are in southern Indiana. The only short line railroad in the Indiana coal field is the Algers, Winslow, and Western, which operates 16 miles of line in Pike County. From Oakland City Junction, where it has connections with the New York Central and with the Southern Railway, the A. W. & W. extends northeast to Cato and southeast to Enosville, in districts of active strip mining. Exclusively a coal carrier, this line has the largest roster of motive power of any of the short lines, with four heavy steam locomotives actively in use.

Although the cement-manufacturing industry at Speed (nine miles north of Jeffersonville) is located on the line of the Pennsylvania Railroad, it is further served by the Southern Indiana Railway, which forms a connection at Watson with the Louisville-North Vernon line of the Baltimore and Ohio. The Southern Indiana Railway consists of a portion of the former electric interurban line between Jeffersonville and Scottsburg. The trolley poles still stand, but the road is now operated by a diesel locomotive, hauling carload freight in one round-trip per day over the five-mile run.

A third industrial short line is the Twin Branch Railroad, which reverses the function of the Algers, Winslow, and Western: the Twin Branch hauls coal two miles from a point on the New York Central main line three miles east of Mishawaka, to the Twin Branch generating plant of the Indiana-Michigan Utilities Company, on the St. Joseph River. In contrast to the nature of its cargo, the Twin Branch is the only electrically-operated short line in Indiana.

Of the two general-service lines, the Central Indiana Railway is the longer and more active. Formerly extending almost the width of the state—from Brazil to Muncie—the Central Indiana has been reduced at

both ends to its present function as an east-west link between Lebanon and Anderson. Although operated independently, this road is owned jointly by the New York Central and Pennsylvania systems, and interchanges freight almost exclusively with these roads. In addition to local handling of coal, grain, lumber, and miscellaneous freight, the Central Indiana directly serves a group of important industries, notably the bottle-manufacturing plant at Lapel and the rubber fabricating plant at Noblesville. Using a diesel road-switching locomotive, the company operates a round-trip daily over the 42-mile line.

The Winona Railroad, like the Southern Indiana Railway, is formed from a segment of an earlier interurban line, which ran from Indianapolis to Elkhart and South Bend. It operates at present between New Paris and Warsaw, paralleling State Highway No. 15. The Winona Railroad is unique among the short lines of Indiana in two respects: it is the only line which is paralleled throughout by a standard steam railway (a branch of the New York Central), and it is the only short line presently scheduled for abandonment. Unfortunately, this line lacks the industrial connections which favor the Central Indiana Railway, although a large gravel pit at Leesburg is served exclusively. Beyond this, with minor exceptions, the functions of the Winona are duplicated by the New York Central. One diesel-powered train is run daily from Warsaw to New Paris and return.

The position of the short line railroads may be summarized in the following terms: (1) under present circumstances, the majority of the short lines in Indiana are returning a reasonable profit; (2) only the two coal-hauling lines are performing services which could not reasonably be duplicated by existing railways or by motor transportation, i. e., except in the cases of the Twin Branch and the Algers, Winslow, and Western, short line abandonment would not work a hardship upon industries or communities; (3) Indiana interurban lines, paralleled almost mile for mile by steam railways, failed chiefly because of dependence upon passenger traffic. At present, only the Ferdinand Railroad has passenger accommodations, and only the Winona is paralleled by another railroad; (4) existing short lines are kept in operation by a threefold combination of conditions: (a) "industrial inertia," (b) performance of a certain class of transportation functions, even though not in every case essential, and (c) civic or entrepreneurial interest and support.

Indiana's Comparative Richness

Stephen S. Visher, Indiana University

Introduction

About thirty years ago, Indiana was compared with other nearby states in various respects. A paper in the Academy *Proceedings* for 1922 summarizes this comparison, as do the final chapters in *Handbook of Indiana Geology* (published by the State Department of Conservation), and *The Economic Geography of Indiana.*

These earlier studies disclose that Indiana's small size (thirty-seventh state), obscures its richness, because in many statistical respects it ranks below the larger states. However, the total for a state is often less significant than is the wealth per square mile. When the area is considered, Indiana is exceptionally rich, one of the best agricultural states, with high rank in many other respects.

Recent Field Studies

What further light on comparative wealth has appeared?

Although frequent studies were made in subsequent years of other regions, with comparison to Indiana almost continually in mind, special efforts were made along this line recently. Hence the following summary supplements the earlier discussion significantly. In 1950 and 1951, I crossed the continent from the Atlantic to the Pacific six times, traveling by day chiefly by auto or by airplane. Thirty-eight of the states were visited, many of them repeatedly. Large areas were seen well. Canada was visited repeatedly and extensively. Almost the entire length of Cuba was seen, partly from the air, and representative bits of northern Mexico. These recent studies supplement earlier extensive trips in Europe, Asia and Australia, and residence of years' duration in Illinois, South Dakota and Minnesota; months have been spent in each of Arizona, Wyoming, Montana, Connecticut, Washington, D. C., Europe, Australia, the West Indies, and in the Pacific tropics. These observations afford vital background for the following conclusions.

How can Indiana be compared with the areas I know and with other areas? Let us consider size, population, production, elevation, topography, soil, forests and grass, minerals, climate: temperature, precipitation, storms, drouths, freezes, and also water supply, scenery and location.

Indiana's Elevation

Indiana's average altitude above sea-level is about 800 feet, which is only one-third as high as the average land of the earth. Some of the advantages of its relatively low elevation are easier tranportation, reduced erosion and better climate, especially smaller climatic extremes.

Indiana's average elevation is about the same as that of Michigan and Illinois, somewhat less than that of other midwestern states, and notably less than that of most of the United States. About three-fourths of the land of the world is higher.

Indiana's Topography

Indiana is mostly a gently rolling plain—little of the state is hilly, none of it is really rough or mountainous. Sizeable areas were formerly poorly drained, but most of them are now artificially drained and are choice farm land. As compared with most areas of comparable size and shape, Indiana is relatively level. For example, Kentucky, Ohio, Wisconsin and Missouri have distinctly more rugged land than Indiana. About three-fourths of the United States is rougher than Indiana, and of the other one-fourth, some parts have much land that is too level, for example, Florida and Maine. Indiana is better topographically than is three-quarters of the world's land. One of Indiana's significant resources is the large percentage of its land that is topographically suitable for agriculture, for rapid transportation, and for the construction of buildings.

Indiana's Soil

Indiana's soil is mostly good, though the average ranks appreciably below the best soils of the world, which are found in grasslands, for example, in eastern Dakota and in the Black Earth section of Russia. Indiana's soil is rendered less rich by the extensive leaching due to the abundant rainfall, and to the fact that most of Indiana was formerly forested. Forest soils are less excellent than are prairie soils.

Perhaps ten percent of Indiana's soil is relatively poor, but even it is better than the poor soils of most of the world. For example, the sandy soils of Indiana yield well as compared with the sandy soil of the Southeast and many other areas. This is because, as a result of glaciation, Indiana's sand is less pure quartz.

Indiana's average soils surpass the average for Michigan and Wisconsin, Ohio and Kentucky, and all the more southern states, and also the average of the entire western half of the United States. They are also better than the average of all the states east of Indiana. Indiana's soil ranks below the average of Illinois and Iowa, and below the better third or fourth of several other states, from North Dakota to Texas. But the soils in the poorest third of those states are distinctly poorer than the soils in the poorest third of Indiana. Their poorness is mostly due to the extensive sandiness, rockiness, or alkali, but is partly due to climate. Soil that is too dry or too cold is, of course, of little value. Very little of the dry west can be irrigated because there is insufficient water.

Indiana's Forests and Grass

Formerly about nine-tenths of Indiana was forested, most of it with valuable hardwood trees. The clearing of the land to permit

farming was laborious, but it was done too completely. Indeed, at least one-tenth of Indiana ought to be wooded, and presumably will ere long be reforested. The fact that valuable trees grow as readily as they do is an advantage of significance. In this respect, Indiana is more fortunate than is most of the world. Apparently less than one-fourth of the world's land is as favored in this respect. Indiana even surpasses most of the favored Midwest in this respect, and far exceeds most of the other states.

Grass grows so well in Indiana that in the carrying capacity of pastures, it ranks almost at the top among all the states, according to impartial findings of the U. S. Department of Agriculture. Indiana's chief crops, the small grains and corn, belong botanically to the grasses. Their exceptionally large yields reflect the suitability of Indiana for grasses.

Indiana's Minerals

The most valuable minerals in Indiana are water and soil. They are so abundant that they are "taken for granted" by most Hoosiers. For such persons, coal is Indiana's most important mineral, followed by oil and gas. Sand, gravel and stone are minerals of even greater total or potential value than coal, but, like water and soil, they are often taken for granted.

In coal production and reserves, Indiana ranks among the upper one-tenth of the world. Several states are ahead of Indiana in present production of coal, oil and gas, but more than three-quarters of the states are far behind. Indiana's production and reserves of these minerals are far greater than those of three-fourths of the world's countries, irrespective of their size.

Indiana has no production of metals, but neither do most other parts of the world.

In stone, gravel and sand supplies and output, Indiana is more fortunate than is two-thirds to three-fourth of the states and countries.

Indiana's Climate

Climate is a resource of special significance. Without suitable climate, most other resources can be used only with great difficulty. Indiana has sufficient warmth for several highly valuable farm animals and crops, and generally has sufficient moisture for them; it has comparatively few disastrous storms. Indiana's climate admittedly is not ideal. The summers are partly too hot, and the winters have insufficient sunshine, and are partly too cold; torrential rainfalls, "cloud bursts", and spells that are too wet or too dry occur fairly often, and hailstorms, tornadoes, icy-coverings and fog are fairly frequent.

However, the climate of every other part of the world likewise is imperfect. A large share of the world is characteristically too dry, or too cold, or too hot, or too monotonous, or too extreme. Somewhat detailed comparisons have been made in *Climate of Indiana,* and elsewhere, between the climate of Indiana and that of other parts of the

world. Indiana's climate is clearly better than that of four-fifths of the world. Certainly little of the world has a climate better suited to the development of the type of life we desire. The greater dependability of Indiana's climate than that of most other areas is shown by the greater average yields of crops, and in several other ways. The contrast in the total yield of crops in a bad year and in a good one is notably smaller than in most states. Indeed, Indiana never has a year when some one of its major crops does not do well. The worst year of record in Indiana had a total agricultural output of two-thirds the annual average. By contrast, most of the world has seasons when the total crop harvest is considerably less than half of the normal output. The climate of Indiana is distinctly more stimulating to human activity than that of the regions south of Indiana, and more dependable than those of areas to the west or north.

The amount of land rated by the U. S. Department of Agriculture as "high quality crop land" is an excellent evidence of the suitability of the climate, soil, and topography for agriculture. Indiana has a larger acreage of Type 1 land than all but three larger midwestern states, and a larger area than the total, combined, area present in thirty other states. The area of such choice land is larger in Indiana than in the total continents of Australia and Africa. Asia has considerable land of comparable agricultural value only in small parts of northern India and south-eastern China. South America has comparably choice land in only a small area near Buenos Aires. Canada, Mexico and Central America have almost no land of the high quality of the better half of Indiana.

Indiana's Water Supply

Indiana has relatively abundant water supplies largely because the climate is humid. The abundant rainfall renews the underground water supply, the many streams, and the lakes and reservoirs. Geologically recent glaciation yielded many gravel deposits, much sand, and many glacial lakes, all of which contribute notably to the State's water supply. One of the highly significant aspects of Lake Michigan is that it offers an unlimited supply of water to industries requiring much water. For example, Gary uses far more water than does Indianapolis.

The large amount of water available in Indiana has greatly facilitated its industrial development. In most of the states, the water supply is far less adequate than it is in Indiana. Many a site otherwise fairly suitable for industrial development is prevented from great growth by inadequate water.

Scenery in Indiana

Although Indiana lacks spectacular canyons, waterfalls, and mountains, it has several notable limestone caverns, splendid sand dunes, picturesque gorges, and many attractive valleys, hills and plains. The

autumn colorations of the trees and shrubs are widely admired. A haze which is classed by artists as exceptionally beautiful adds to the attractiveness of widely-admired Brown County. Other scenic aspects which are more common than in most other parts of the world are hoar-frost, and ice-blanketed twigs and branches. The clouds of Indiana contribute more beauty than do the clouds of much of the world. Indeed, few Hoosiers realize that much of the world is generally either overcast or cloudless.

It is believed that despite the lack of spectacular scenic features, Indiana surpasses three-fourths of the world in scenic attractiveness of varied types. Every part of the world has, admittedly, scenic aspects, but most areas possess far fewer types of scenery than does Indiana; they have more scenic monotony.

The state parks of Indiana are exceptionally successful in making available to the public the scenic advantages of the state. In this respect Indiana is far ahead of most of the world—it is in the top five percent.

Locational Resources of Indiana

Indiana is exceptionally finely located, in the midst or heart of a progressive, rich, friendly area, near large markets and abundant raw materials. Only a small share of the world is nearly as favorably situated. Indiana has benefitted greatly from its favorable location. As the locational factor is of increasing significance (as a result of increased commerce and less isolation) it seems highly probable that Indiana's favorable location will have augmented importance, as North America develops. Conversely, the areas of the world which have relatively poor locations are declining in importance. Indiana's location is more favorable for its people than is the location of nine-tenths of the world's other tracts of similar shape and size.

Conclusions

Although in each of the resources here considered, Indiana is not ideal, and is surpassed by a few percent of the world, Indiana's average rank is very high. Areas which surpass it in one or two resources are generally far behind in respect to other important resources. In average rank as to these great resources, Indiana is surpassed by less than one-tenth of the world.

The conclusion that Indiana ranks very high as compared with most of the world reflects not local patriotism (I am not a Hoosier), nor youthful enthusiasm. Instead, it is based on considerable knowledge of other parts of our country and of the world, and on mature judgment.

Indiana's comparative richness justifies increased efforts of its citizens to make its leadership among the states even greater than at present.

HISTORY OF SCIENCE

Chairman: R. E. GIRTON, Purdue University

D. Roller, Wabash College, was elected chairman for 1952

ABSTRACTS

The pioneer period in the study of Indiana vascular flora. RAY C. FRIESNER, Butler University.—The pioneer period in the study of Indiana vascular flora was carried on by three types of naturalists: (1) travellers who passed through the state or made only brief stays, collecting and observing, but moving to other centers for study and writing of their results. Such workers are illustrated by Andre Michaux (1795), Francois Andre Michaux (1802), David Thomas (1816), Thomas Nuttall (1818) and Alexander Phillip Maxmillian (1832-33). (2) Professional botanists of the general area but residing outside the state such as Constantine Samuel Rafinesque, residing in Lexington, Kentucky; John L. Riddell, and Alphonse Wood, whose Class Book of Botany was widely used in the later years of the pioneer period. (3) Men of other professions whose avocational interest did much to advance our knowledge of Indiana vascular flora. Dr. Asahel Clapp, physician of New Albany, was the most noteworthy in this last group.

Joseph Priestly, apostle of reason. RAYMOND E. GIRTON, Purdue University.—Joseph Priestley, English theologian, philosopher, and scientist was born in Yorkshire in 1733. His formal education was concluded at the Dissenters' Academy at Daventry where he studied for the ministry in an atmosphere of critical tolerance and freedom. Priestley served a half dozen churches in England and America including Unitarian congregations in Leeds, Birmingham, London, and Philadelphia. As the result of his reliance upon investigation supported by reason, he abandoned Calvinism and the Doctrine of the Trinity in religion, supported the causes of the American and French revolutions in politics, and carried out a great deal of experimental work in science which led to the discovery of oxygen and its production by plant life. Priestley's contribution to society, therefore, was his fearless use of reason in the pursuit of truth in these different fields of human activity.

Early experiments with the power of intelligence—a survey of ancient Greek science. W. E. HOWLAND, Purdue University.—The achievements of the Greeks not only in art and philosophy, but in many fields of science was truly astonishing as the record clearly shows, incomplete though it is. "How did it happen that they accomplished so

much?" is one of the puzzling questions of history, and another is "why was this period of scientific history followed by so long a one of relative inactivity?". A partial answer to the first of these questions appears to lie in the conditions of almost perfect freedom from the restraining hand of tradition that prevailed in these early Greek times. There are doubtless many reasons for the scientific blankness of the subsequent pre-Renaissance period of European history, but at any rate the Greeks are not to be blamed for the fact that they were followed blindly by those who came after them. The Greeks did not regard themselves as absolute authorities; the student questioned and corrected his teacher and apparently was encouraged to do so; think of Socrates. Their way was one of doubting and of actively using both the imagination and the reason. If a Greek had been heard to say, "Thou shalt not contradict Aristotle," he would have been laughed out of court. This particular stupidity was the invention of men whose minds with few exceptions were enslaved, who mouthed the words but missed the method, and above all the spirit of inquiry of early Greek Science.

The electrical researches of Francis Hauksbee. DUANE ROLLER and DUANE H. D. ROLLER, Wabash College and Harvard University.—Francis Hauksbee's 11 papers on the barometric light and electricity (1705-1709) have been studied to determine the experimental methods and modes of thought that he employed and that had the greatest effect on the progress of his work, to compare his methods with those of earlier and later experimentalists, and to trace the effects of his work on subsequent electrical researches. For some of his most important discoveries he has not received adequate credit. Various factual errors and misinterpretations of his work appear in practically all histories of science and textbooks that mention him at any length. Many textbooks do not mention him at all. Yet he was the most active and successful experimentalist of his age; he published 34 papers, all of them in the *Philosophical Transactions* and all within a period of 5 years. The present study is one of a series on early electrical concepts and methods financed in part by a research grant from the Indiana Academy of Science.

Josiah Willard Gibbs, an historical appraisal. ANDREW A. SHEROCKMAN, Evansville College.—This paper gives a brief biographical sketch of the life of Josiah Willard Gibbs, and an appraisal of his contributions to exact knowledge, to industry, and to education. This is the 75th Anniversary of the presentation of his third paper entitled "On the Equilibrium of Heterogeneous Substances," before the Connecticut Academy of Science. It is considered his most important contribution to physical science, and is largely responsible for the founding of physical chemistry.

The evolution of Indian implements for grinding corn. PAUL WEATHERWAX, Indiana University.—An examination of the implements used in ancient times for grinding corn in the various parts of the

maize-growing areas of North and South America shows some interesting lines of evolution. Proceeding from the simplest sort of rough stones, a series of variously shaped implements can be traced to the point where they are highly elaborated and have only a ceremonial significance.

Early Health Conditions in Indiana

Don E. Bloodgood, Purdue University

In these trying times there may be some satisfaction in referring to the "good old days." On the other hand it may leave one feeling like the little boy who pounded his finger because it felt so good when he stopped.

It must be admitted that most of the severe epidemics of the nineteenth century came and went without anyone knowing why they came or why they disappeared.

There have been many sicknesses that have killed, maimed, or laid low the people of Indiana; to talk about them all would be a most gruesome tale. The four sicknesses, cholera, malaria, milk-sickness and typhoid were selected for discussion because they are sicknesses that can be controlled by good environmental sanitation. Yes, all of these sicknesses have visited the people of Indiana during the past one hundred and fifty years.

Today there seems to be but little similarity in the symptoms of the four sicknesses, but I am sure from my readings that even the doctors were confused in the early eighteen hundreds. The most serious epidemics of these sicknesses came and left before the real causes were understood. It is reasonable to believe that there was practically nothing that man did that curtailed the diseases or lessened the resulting loss of life during the early days in Indiana.

It was not until 1883 that Koch identified the bacteria that caused the intestinal infection known as cholera. The main symptoms of this disease, you may or may not know, were and still are where the disease exists "severe, constantly flowing diarrhea, vomiting, collapse, cramps in the muscles, and suppression of the flow of urine from the kidneys".

The scientific control of malaria also started about 1880 when Laveran, a French army surgeon, found the parasite in human blood. It is well known that the chief symptoms of malaria are intermittent chills and fever.

Milk sickness is not a disease but a poisoning of animals that have eaten the weed white snake root. The poison, an alkaloid, can be passed on to humans who develop the same symptoms as affected cattle—they are shaking and convulsions. People have become poisoned by drinking milk from animals not apparently poisoned.

Typhoid fever, the intestinal infection caused by the typhoid bacillus, is and has been much talked of. The symptoms are: first, headache, pain all over the body, a feeling of exhaustion; then chills, fever, nose bleeds, serious disturbances of the bowels resulting from ulcerations in the intestines. It was not until 1880 that Eberth discovered the organism and it was sixteen years later that Wright developed a method of protecting people by inoculation.

Similarity of symptoms such as chills or convulsions and fever in all four of the sicknesses explains some of the confusion found in early reports by doctors and newspaper reporters. The confusion of sickness identification makes it impossible to report on each of the four sicknesses in separate chronologic order. Information from newspaper and old diaries can easily be placed in proper sequence but some of the interesting statements found in histories and other published works are not so easily placed in proper order.

An attempt will be made to give some idea as to the health of the people in Indiana from the time that it gained statehood in 1816 until more recent times. Dr. Harding (4) wrote in his report, "The graver forms of periodical fever were scarcely known, and the country was considered quite healthy until about the year 1819, when both intermittent and remittent fevers became quite prevalent, and decidedly malignant. This state of things continued during the summer and autumn for three or four years. Within this period a considerable portion of the adult male inhabitants lost their lives, while women and children suffered less". In reading about Indianapolis it was noted that one reporter (5) stated that more children than grown-ups died of the fevers. Dr. Schweitzer (6) states in her historical writings that "in 1820 there was a visitation of intermittent and remittent fevers much more malignant than the ordinary fever and ague. Many new towns were almost depopulated". It is recorded that there were seventy-two deaths (one-eighth of the entire population) in Indianapolis in one year. The sale of lots in the then recently platted capital city had to be postponed until the following year. In Dr. Mitchell's notes on Indianapolis he states that "of 1000 souls in town on the donation, and the farms surrounding the town, at least 900 sickened during the prevailing epidemic." Kemper (5) states that he obtained from reliable sources that "in the fall of 1821 there was only one well man in the city of Columbus. This man, a stalwart six-footer, who evidently had been brought up in a swamp was cook and nurse to the entire community" and Kemper says then, "His memory deserves to be perpetuated," but neglects to give the name of the Good Samaritan. It is quite certain that this siege was malaria because of the vivid description of the fever and chills. During the hot stage, a statement is recorded that the physician tried to promote perspiration by internal and external remedies. After this the stomach and bowels were prepared for the reception of Peruvian bark that was given in spirits in large quantities.

In Vincennes in 1821 (10), one third of the residents were "in their beds with sickness". The whole of the Wabash country was infected. In "Recollections of the Early Settlement of Carroll County" (7) it says, "On the 12th day of October, 1824, Henry Hezekiah and Abner Robinson, with their families, accompanied by Joseph Clymer and his son, and a Mr. James French, started for the Wabash Valley. On passing through Richmond and Centerville they were annoyed by the croaking predictions of 'ill luck' uttered on all sides. 'You will never

get through', says one. 'You will die if you go to the Wabash; everyone that goes there dies in less than a year,' joined another."

Some of the early residents had a belief that swamps and damp air had something to do with the sickness but at least one other believed differently because he wrote, "In 1830 the summer was dry and sickly. Unfortunately for Delphi the unusual amount of sickness gave it a bad name from which it did not recover for many years".

"The Indiana Magazine of History" (2) states, "On the whole the distress of the families during epidemics of fever was pitiable. Often there were not enough well people to care for the sick. Provisions gave out and it was difficult for the sick people to obtain food. A poor settler of Hamilton County describes conditions thus: 'In September sickness set in in earnest; nearly everyone would be down at the same time, not one to help the other when the ague was on'."

The "Indiana Journal" of June 14, 1832 carried a short item stating that cholera was reported in the City of New York and that several cases had terminated fatally. The next item that I found in this same paper was in the November 10, 1832 issue. It carried the date line, Madison, Nov. 5 and it was a letter to the readers and it read as follows: "Gentlemen—I have just time to say to you that the cholera has to all appearances, abated. We have had no case since Thursday last, 12 o'clock. That it has left our borders I am not prepared to believe, as many of our citizens are complaining and are under medical discipline. I believe, however, that here as elsewhere after the first attacks, which in a majority of cases prove fatal, the disease yields to medicine.—"

The "Wabash Mercury" of July 18, 1833 carried an article from the "Wabash Courier" headlined "Cholera at Salem". It is quoted as follows: "By a traveler from the South, we learn that the cholera is prevailing in Salem to a frightful extent. In five days, one hundred are said to have fallen victims to it. Among this number, we regret to record the name of the venerable and upright Benjamin Parke, District Judge of Indiana. Salem contains a population of about 800 souls, making the death in a ratio of one in eight. This mortality, if true, is unparalleled in the progress of the disease in our country. We hope that the reports that reached us may turn out to have been exaggerated." The "Indiana Journal" of July 20, 1883 said, "The disease has visited Salem in its most unrelenting form—business is prostrate, and a large portion of the inhabitants have fled from the scene of the distress and death." In reading the old newspapers I found that they were inclined to minimize the story about the epidemic in their own community but quote even the wildest of tales about neighboring communities. To illustrate this the "Wabash Mercury" of July 18, 1833 is quoted, "From Greensburg, we learn that the cholera has broken out with great violence and in a few days thirty deaths had occurred", "By recent intelligence we learn that the cholera was raging at New Castle, Henry County. Between forty and fifty cases, and several deaths have occurred during the past week." These may

have been very true but not a word about the health of the people in Lafayette. The "Wabash Mercury" of July 25, 1833 had items informing their readers of cholera cases in Bedford, Paoli, Rockville, Mount Vernon and Covington and three weeks later they reported cases in New Castle, Richmond, and Indianapolis.

Perhaps more authentic information on epidemics can be found in the technical writings of the medical doctors of these early days. Dr. George Sutton (9) has written extensively about the epidemics of cholera in southern Indiana. He not only treated patients that had cholera, he and most of his family had the disease. He has this to say about the 1833 epidemic in Dearborn County. "A steamboat ascending the Ohio River, in the month of May, 1833, landed near the mouth of Tanner's Creek to bury one of the deck hands who had died of cholera. Two men, one an old citizen of Dearborn County, by the name of Page Cheek, were fishing near the place this boat landed. The officers of the boat, seeing these men, employed them to bury this body, which they did. All the next day, Cheek, who lived near the mouth of Wilson Creek, about a mile from Tanner's Creek, plowed in the corn field, apparently perfectly well, but during the night he was suddenly attacked with cholera, and died after a short illness. His brother-in-law, Eli Green, went with his wife to the funeral. They resided near Hartford, about six miles from Cheek's residence; within a week both Green and his wife died with cholera, and in a few days after their deaths, three of their children also died, making five deaths out of this family of seven persons. The disease spread through the neighborhood, and soon appeared at Aurora, where a large number of deaths occurred, among the number some of the most prominent citizens. It is impossible now to ascertain the number of deaths which occurred, as no account of this epidemic in Dearborn County was ever published."

Cholera received the most attention in the papers of this period but in the "Wabash Mercury" of September 12, 1833 there was an article (not unlike our columns of letters to the editor) that apparently had been written in reply to one previously sent in by a traveler that quoted an elderly lady. It said, "The milk sickness is not as prevalent between Logansport and Vincennes as reported by a traveler quoting an 'elderly lady'." The elderly lady may have had some foundation for her statements because the "Wabash Mercury" of November 14, 1833 carries three columns describing milk sickness and sick stomach and how to treat them. A tinge of what nowadays is called propaganda can be detected in the following quotation from the aforementioned letter, "The Wabash country for the past three years, has been as healthy as any other section of the Union, and the emigration too is unexampled in the history of any new country; and as the population increases, the diseases consequent to a new country disappear." Perhaps the anonymous correspondent was interested in some commercial venture that depended upon new people coming into the country. I am sure that there is overwhelming evidence that the years 1830-33 were far from being healthful.

Schweitzer (6) writes, "Up until 1836 malaria returned each year with but slightly lessening severity, and the distress was well nigh universal, and from the first of July till the first of October all work and business ceased and the few well ones devoted their time to the care of the sick."

It is not easy to conclude that malaria was less dangerous than cholera when we read in Kempers, "Medical History of the State of Indiana," "The doctors found the ague, in many instances, more than a match for their skill. It was of the real shaking variety, the chill lasting not infrequently three or four hours, to be followed by raging fever. So malignant was this type of fever that as many as three or four deaths of adults have occurred in one family in less than forty-eight hours. Peruvian bark and calomel would temporarily check the fever, but cold weather seemed to be the only thing that would stop this dreadful scourge." Perhaps the free usage of the lancet to bleed practically all patients coupled with the more than free usage of calomel, tarter emetic, castor oil, and salts did not decrease the mortality rate among the fever ridden. The doctors tried to do their best for their patients even though they themselves were ill. At one time in the town of Franklin, only two out of the five physicians were able to answer calls. Their services were so much needed that they rode from place to place on a gallop. Often they traveled not less than fifty miles per day (10).

Dr. Sutton (9) says, "In 1838 the Laughery Valley, which is a few miles below Aurora, was visited by a malignant form of malarial fever —I think I can safely say that every family residing along this valley, for eight miles from the Ohio River, was more or less unwell, and in many families all were bedfast."

Hamelle (3) wrote, "Princeton Township in White County was for thirty-five or forty years known as one of the bad fever districts of the County. The worst season of all was reported in 1844-45. In July and August there were not enough well persons in the township to care for those who were seized with it." Dr. Schweitzer writes that in a personal interview with Dr. P. H. Jameson she was told that in the summer of 1845 hardly one person in six in Indianapolis escaped having what is now believed to have been malaria.

In 1846 Kemper (5) says congestive fever (probably malaria) as it was called appeared in Hancock County. One doctor contending that bleeding was the only remedy and he lost every case. A consultation of all physicians in Cumberland was called and it was agreed that "full and frequent doses of quinine" was the best treatment. A great hindrance to the use of quinine was its cost and the scarcity of money. An ounce of quinine cost about the amount that could be obtained from the sale of one fat beef, eight dollars.

The second serious epidemic of cholera in Indiana was first indicated by cases in Aurora in 1849 (8). About May 1st the residents began having diarrhea, with sudden attacks of vomiting and purging, profuse perspiration and a "remarkable depression of the vital powers"; some who neglected treatment developed the characteristic rice water

discharges, dark and shrunken appearance of the skin, and severe cramps of the extremities. On May 13th there were four deaths in Aurora, on the 14th large fires were made at the corners of the streets and cannon were fired every twenty-five minutes for four or five hours. There were fourteen deaths on this day. Between the 27th of May and the 2nd of August, 132 of the city's inhabitants had died. There were 1600 of the people who left the city and of these only 13 died. Dr. Sutton wrote to his fellow physicians in some of the counties of the state and learned that cholera was prevalent in the following counties in 1849-50-51:

1. Franklin
2. Ripley
3. Ohio
4. Switzerland
5. Jefferson
6. Jennings
7. Bartholomew
8. Decatur
9. Shelby
10. Rush
11. Union
12. Wayne
13. Henry
14. Grant
15. Allen
16. Carroll
17. Tippecanoe
18. Johnson
19. Putnam
20. Clay
21. Knox
22. Dubois
23. Washington
24. Floyd
25. Spencer
26. Vanderburg

In July and August 1850 there were 28 deaths from cholera in Mt. Sterling, a little village a few miles north of Vevay. Dr. Thompson reported that there were no cases in Wabash County and Dr. Brackett reported from Fulton County saying that there were no deaths from cholera there during 1849-51.

Delphi was worried about the cholera epidemic and to protect the peoples of the city the following ordinance was passed:

"Be it ordained by the Mayor and Common Council of the Town of Delphi that all persons passing or traveling from places infected with cholera, be prohibited from staying in our midst more than time sufficient to procure a meal of victuals; that all places of public entertainment be required to prohibit the stay of all such persons for a longer time; and that our town citizens, except physicians, be hereafter prohibited from going to or visiting places, near or distant, where the cholera is prevailing, unless there is absolute necessity for so doing; and any person or persons offending against or violating any of the provisions of this ordinance be fined in any sum not less than three or more than ten dollars for each offense." When Stewart (7) recorded this ordinance he added, "Note the cholera was prevailing at Lafayette at the time of the passage of the above law, and the citizens of that city were very indignant at the Mayor and Council of Delphi, on account of the prohibitory ordinance."

That there were deaths from cholera in Lafayette there is no doubt, James P. Jenks, the editor of the "Daily Courier", died after

a severe attack of chills and fever followed by a violent attack of dysentery. It is reported that there were 300 deaths in Lafayette during the epidemic.

Dr. Ezra Read of Terre Haute wrote to Dr. Sutton, "We have been singularly and entirely exempt from cholera—but a single case has ever occurred here. A traveller died at this town in 1850, having passed through some districts in Illinois where cholera was prevailing. He had symptoms when he reached the hotel, and died in about six hours. We can scarcely assign a cause for our exemption from this disease. It has prevailed on the Wabash River towns, both above and below Terre Haute, and at Paris, Illinois, 20 miles west of us."

Vogel (10) said that milk sickness destroyed the value of lands in neighborhoods that were known to be afflicted with it.

In the biographies "The Doctors Mayo" Clapesattle says that both Dr. and Mrs. Mayo had weathered attacks of chills and fever. The Doctor is quoted as saying, "One hour you are so hot you can't get cool; the next you are so cold you can't get warm. Hell, he insisted, is a place where people have malaria." One day in the summer of 1854 in the midst of a chill he stamped into the barn, hitched up horse and buggy, and shouted to his startled wife as he drove off westward, "Goodbye, Louise, I'm going to keep on driving until I get well or die."

Dr. Harding (4) quoting Dr. Woody, wrote in 1853, "During the last winter, typhoid fever was unusually prevalent. Indeed this form of disease seems to be on the increase; while on the other hand, there seems to be a diminution of remittent and intermittent fevers, as well as all diseases of a malarious origin." Esarey (1) wrote, "Typhoid fever would scourge a whole community until its mysterious course was arrested by the autumn rains or winter. In the year 1859 by way of example, the deaths (from all causes) in August, September, and October, the typhoid months, were 1500, 1633, and 1364; while for the three preceding months there were, all told 3358 deaths and for the preceding three there were 2991; an excess of 1139 over the preceding spring months and 1506 over the succeeding winter months. The death toll of typhoid fever seems to have been about 500 persons per month though the total number directly attributed to this malady was 1763."

Dr. Schweitzer said that, "The fevers (malaria) became more severe. They steadily increased in virulence up to 1856; after that time, they gradually decreased." The last widespread epidemic was in 1865.

The very early newspapers did not carry regular notices of deaths. "The Daily Journal" of 1866, had started the practice of publishing death notices and those listed on Saturday morning, August 11, were: Margara Mattler, age 6 years; Mrs. Mary Browning, age 22 years; William McCoy, age 33 years; Cyrus Blauvelt, age 12 months and 12 days; and John Duncan, age 18 months. It is interesting to compare this listing with a recent one in the "Lafayette Journal and Courier", (Saturday, December 9, 1950). James D. Sinclair, age 90; John Funk, age 74; Mrs. Sadie E. Piggat, age 79; and Mrs. Ida L. Paul, age 80.

Vogel (10) said, "No part of America, outside of the tropics, was more subject to malaria visitation than the rich lands in Indiana. So alarming was the mortality that the General Assembly of the State set apart a day for public prayer and supplication to the Almighty God that He might bless the country with fruitful seasons and bring health and peace to the unhappy citizens."

By 1885 malaria had practically disappeared from many sections of the state. Typhoid fever was reported to have reached the highest incidence in 1900. There was not a single month in any year up until 1937 when there was not a reported death from typhoid in Indiana.

Eighteen cases of malaria is the smallest number reported in Indiana in any one year and this was in 1941 prior to the return of many individuals from other parts of the world where they had contracted the disease. There were 643 cases of malaria reported in 1945.

In 1949 there were 47 cases of typhoid in Indiana.

There have been no reported cases of cholera in Indiana in many years. There was one case of milk sickness reported in 1935.

Perhaps our present day problems should not look so difficult to us when we realize that we have been almost entirely relieved of the burdens and fears of those who lived in Indiana in the early days.

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The Charter Members of the Indiana Academy of Science

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It probably is too late now to determine the exact number and identity of the Charter Members of the Indiana Academy of Science. However, there should be no question about the names signed to the original Constitution of the Academy, names appearing in the Treasurer's Book for the first meeting, and names of those participating in the program of the First Meeting in December, 1885. Also the names of a number attending the first Spring Meeting, held at Brookville in 1886, should be considered, since Charter Membership was apparently held open for some time after December, 1885. In fact a number of individuals who hitherto have been considered and listed as Charter Members do not have their names appearing in any known published Minutes or other known records before the Second Meeting held in December, 1886. However, in the Minutes for the Second Meeting some half dozen names of outstanding and active members of the Academy also appear and they undoubtedly became members some time during the first year of the Academy's existence, yet their names have never appeared on any published list of Charter members. While, of course, no decision can be made as to their true status, and while it probably is of no great importance, nevertheless the facts now known are worthy of consideration.

Several years ago Dr. John S. Wright discovered in the *Indiana Pharmacist* for January, 1886, pp. 267-268, Minutes of the First Meeting, in which the names of forty individuals were listed as the Charter Members. However, there were in the Minutes the names of six other individuals, not listed among the Charter Members, who were either active in reading papers, or having papers read by others, or serving on some committee. Since I had previously made a study of the Charter Membership and had stated in the *Proceedings*, volume 44, p. 31, that there were 68 Charter Members, this discovery of Dr. Wright's aroused me to make a further study. For a number of years the original Constitution of the Academy was lost but it was finally found among some old papers in the Earlham College Library and sent to Dr. Amos W. Butler on December 4, 1926, and Dr. Butler reported the find in the Proceedings, Volume 36, 1926, pp. 7, 8, and he gave a list of the names of the fifty-four persons who signed the original Constitution. This last list contained the names of all those mentioned in the Minutes found in the *Indiana Pharmacist* except that of W. H. Ragan who appeared on the Program for the First Meeting. In the Proceedings for 1909, Volume reporting on the Twenty-fifth Anniversary Meeting, pp. 35-37, Dr. Butler gave a list of 37 names, nineteen of whom "are mentioned in minutes of December 29, 1885, as being present and taking part in the meeting," and the other eighteen as names which "appear on the treasurer's book for that meeting, and

they were probably present." This list of eighteen names appearing on the Treasurer's Book produced the names of Seth E. Meek and Joseph Moore, not listed as Constitution signers. Thus far a total of fifty-seven individuals appear to be entitled to be classified as Charter Members, but the names of J. C. Arthur, George W. Benton, A. J. Bigney, W. S. Blatchley, David M. Mottier, R. W. McBride, and Robert Hessler, are not in this list, and all seven have long been recognized as being Charter Members, honored as such, and listed in the Directory of Members as such in the Proceedings for 1922, where such information is given for the first time. And the names of W. A. Noyes, Harvey W. Wiley, J. S. Kingsley and T. A. Wiley, previously considered as Charter Members, have yet to appear.

It appears that Charter Membership was held open through the first year of the existence of the Academy. Some years ago I discovered complete Minutes of Winter and Spring Meetings of the Academy from 1885 through 1888 in **The American Naturalist,** volumes 20-23, 1886-1889, and these Minutes report papers presented on the Programs and much other information. In Volume 21, 1887, pp. 107-109, in the Report on the Second Winter Meeting, the names of W. A. Noyes and Harvey W. Wiley appear. However, the name of J. S. Kingsley does not appear until the year following, which is to be expected, since Kingsley did not come to Indiana University until 1887. Thus one of two facts is true: either Kingsley joined the Academy before coming to Indiana or he was not a Charter Member. However, no objection was ever offered to listing him as a Charter Member by Dr. Butler, Dr. Stanley Coulter and others who were in a position to know. I have found no list giving T. A. Wylie, of Indiana University, as a Charter Member, but his name has nevertheless appeared as such.

If the Charter Membership was held open during the first year one wonders why the names of J. N. Rose, Charles Reid Barnes, George C. Hubbard, C. H. Bollman, Thomas C. Mendenhall and T. C. VanNuys, are not listed among the Charter Members for they all presented papers at the Second Winter Meeting. Finally the name of Henry A. Huston appears among the accepted Charter Membership. Dr. Huston is still living and confirmed his Charter Membership in a communication to me some years ago.

Obviously the matter of Charter Membership is somewhat confused and there appears to be little likelihood of settling it at this late date. Possibly the papers of Dr. Butler would throw some light on the situation if those papers were made available. Below is the List of 69 members considered previously as Charter Members. Following each name are certain letters which indicate where that name appears. The significance of the letters is as follows:

C—Signed the Constitution; P—Listed as a Charter Member in the *Indiana Pharmacist*; Pm—In Minutes in *Indiana Pharmacist* but not listed as a Charter Member; D—Listed as a Charter Member in the Directory in the *Proceedings* for 1922; T—Listed in Treasurer's Book for First Meeting, as reported in the *Proceedings* for 1909; S—Appeared on Program for Second Annual Meeting, as reported in The American Naturalist, Volume 21, 1887, pp. 107-109.

J. C. Arthur (1850-1942) D
Philip S. Baker (1851-1901) C, P
George W. Benton (1862-) D
A. J. Bigney (1864-1929) D
W. S. Blatchley (1859-1940) D
John C. Branner (1850-1922) C, P
A. W. Brayton (1848-1926) C, P
Ryland T. Brown (1807-1890) C, P
J. B. Burris (1859-1935) C
Amos W. Butler (1860-1937) C, P
John L. Campbell (1827-1904) C, P
Arthur B. Chaffee (1852-) C, P
J. B. Conner ( ) C
John M. Coulter (1851-1928) C, P
Stanley Coulter (1853-1943) C, P
D. W. Dennis (1849-1916) C, P
C. R. Dryer (1850-1927) C, P
C. H. Eigenmann (1863-1927) C
B. W. Evermann (1853-1932) C, P
William H. Fogg ( ) C
Morton W. Fordice (1864-1939) C, P
E. E. Glover ( ) C, P
G. K. Greene ( ) C, P
Charles W. Hargitt (1852-1927) C, P
Oliver P. Hay (1846-1930) C, P
Robert Hessler (1861-1942) D
Orlando Hobbs ( ) C
W. DeM. Hooper ( ) C, P
J. N. Hurty (1852-1925) C, P
Henry A. Huston (1858-)
Henry Jameson (1848-1924) C, P
O. P. Jenkins (1850-1935) C, P
J. P. D. John (1843-1916) C, P
D. S. Jordan (1851-1931) C, P
J. S. Kingsley (1854-1929)
Daniel Kirkwood (1814-1894) C, Pm
Lillien J. Martin (1851-1943) C
T. J. McAvoy ( ) C
R. W. McBride (1842-1926) D
Jerome McNeill (1857-1928) C, P
Seth E. Meek (1859-1914) T
David R. Moore (1850-1932) C, P
Joseph Moore (1832-1906) T
David M. Mottier (1864-1940) D
W. H. Mushlitz ( ) C, P
J. P. Naylor (1853-1938) C, P
Fletcher M. Noe ( ) C, P
W. A. Noyes (1857-1941) S
H. L. Osborn (1857-) C, P
D. A. Owen (1852-1930) C, P
Richard Owen (1810-1890) C, Pm
A. J. Phinney (1850-1942) C. P.
A. B. Porter (1864-1909) C
G. W. Puterbaugh ( ) C
E. R. Quick (1851-) C, P
W. H. Ragan (-1908) Pm
T. B. Redding (1931-1895) C, P
J. T. Scovell (1841-1915) C, Pm
W. P. Shannon (1947-1897) C, P
Frederick Stein ( ) C, Pm
J. O. Stillson ( ) C, P
S. P. Stoddard ( ) C, P
Maurice Thompson (1844-1901) C, P
C. A. Waldo (1852-1926) C, P
Robert B. Warder (1848-1905) C, P
L. D. Waterman (1830-1918) C, P
F. M. Webster (1846-1916) C, Pm
Harvey W. Wiley (1844-1930) S
T. A. Wiley (1810-1895)

The History of *Mentha piperita* and Its Economic Importance in Indiana

C. L. Porter, Purdue University

The genus Mentha is included in the dicotyledonous family Labiatae. According to legend, a nymph named "Minthe" was changed by Prosperine into a mint plant. Theophrastus gave the name "Mintha" to the plants of this group, thus honoring the legend. Mintha has been modified to Mentha in modern terminology.

According to the eighth edition (1950) of Gray's Manual of Botany (3) eleven species of Mentha are listed as occurring in the Northern United States. All of these with the possible exception of some varieties of M. arvensis have been introduced from Europe. In a foot note in this edition of the manual the authors state "The Old World species have crossed and recrossed until hundreds of the vegetatively propagating progeny have been described and very unsatisfactorily defined. Many of these have been introduced into this country and have found their way to waste places, roadsides, etc. Only the strongest-marked and definitely naturalized plants, without hypothetical guesses as to their derivation are here recorded."

Mint is mentioned in the Bible (Matthew 23:23), by Theophrastus, Hippocrates and Pliny. Mint is included in monastary records which recommends the herb both for culinary and medicinal use. Henslow in "Medical works of the Fourteenth century" quotes from old monastery records an ancient cure for ulcers. "For an ulcer, take eggs that be rotyne undre an henne whane she sittes to bryng forth byrddes, and breke them and ley them on the sore and it schale sleye the worme for the stynche; and whoso hathe none egg is take thereof the Jus of mynte and it will do the same".

Until the time of the Renaissance the various mints were undifferentiated. The origin of *Mentha piperita* is obscure and there are conflicting opinions as to the origin. According to Gray's Manual of Botany Europeans consider the species to be a cross between *M. spicata*, spearmint and *M. aquatica*, water mint. Miss Kamm (9) in her book entitled "Old Time Herbs" suggests that *M. piperita* may have originated about 1696 as a sport from the English hairy mint, *M. hirsuta*. Pickering (11) in his "Chronological History of Plants" is authority for the statement that peppermint originated in India. The plant was observed in the gardens of Egypt. "Linnaeus states that the species is well known in gardens throughout Middle Europe. It became naturalized in England before the days of Persoon."

Mentha piperita has a high degree of sterility and for this reason it has been a difficult plant to analyze genetically. According to Nelson (10) the sterility "is an evidence of its bybrid constitution." Schurhoff and Schultz believe that *Mentha piperita* is a hybrid with *M. aquatica* and *M. viridis* as the probable parents. But Schurhoff thinks that *M.*

viridis is a hybrid with *M. sylvestris* and *M. rotundifolia* as the parents. If these conclusions are correct it would make *M. piperita* a triple hybrid.

The mints contain essential oils that are valuable in medicine and flavoring. Peppermint oil is used to flavor tooth paste, candy and chewing gum. Fifty percent of the extracted oil of peppermint is used by the chewing gum industries. Menthol, sometimes termed "peppermint camphor", is a derivative of the oil and is valuable for its antiseptic qualities and in the treatment of colds.

The essential oil characteristic of the various mints is derived chiefly from the foliage where it is produced in small glands located most abundantly on the tips, margins, and undersides of the leaves. The oils of different mints have different qualities and hence, impart different flavors. For example, *Mentha spicata,* spearmint, as is well known, has a pleasant flavor, but one quite distinctive from that characteristic of *Mentha piperita.* The Japanese mint, *Mentha arvensis* var. *piperascens* has a bitter taste that is objectionable. Nevertheless, the Japanese mint is the principal source of menthol. Many of the wild mints produce oils with disagreeable flavors. It is unfortunate when such "weed" mints appear in fields of peppermint. Their oils contaminate the peppermint oil and serve to lower the quality of the latter oil. The chewing gum industry is extremely wary of any flavoring in their product which varies to any degree from that to which the trade is accustomed. For this reason the oil extracted from disease-resistant hybrids or synthetic peppermint oil prepared by the chemist has never found favor with chewing gum manufacturers.

The industral history of *Mentha piperita* in the United States begins with the importation of planting stock from England in 1812. The first plantings were made in the vicinity of Ashfield, Mass. The first plantings of this species made in Michigan occurred in St. Joseph county in 1835. There is an area of muck soil in Southern Michigan which is more or less contiguous with similar muck land in Northern Indiana. These muck soils are so well adapted to the culture of mint that this Michigan-Indiana area has become the center of peppermint culture in the United States.

The first plantings of peppermint on the west coast were made in Washington and Oregon about 1919. This western mint is grown chiefly on lava soils. The area there has expanded rapidly until at this date it is somewhat greater than the Michigan-Indiana area. The climate and soil of the northwest produces more rapidly growing plants; larger and coarser than the peppermint grown in Indiana. However, the quality of Indiana mint oil is superior and is preferred by the manufacturers.

The principal mint producing areas in Indiana which include both peppermint and spearmint, quoting from Ellis and Stevenson (2), are "near South Bend, North Judson, Rennselear, Bremen, Nappanee and Columbia City." Acreage in Indiana for 1949 according to Bureau of Agricultural Economics of the U. S. Dept. of Agr. was expected to be 16,000 acres for peppermint and 10,400 acres for spearmint. The yield

per acre in pounds of oil was estimated for peppermint as 29; for spearmint, 27. The total production of peppermint oil for Indiana in 1949 was calculated at 464,000 pounds. Yield of spearmint oil was 281,000 pounds. The price of mint oil has varied from a low of 75 cents a pound to a high of $30.00 per pound. The current price is $7.00. The mint crop therefore on a comparatively limited acreage in Indiana amounts annually to more than a million dollars. The individual farmer in years of high yield and good prices gets his maximum return with a mint crop on muck soil. William Gehring owner of the Gehring Farms is among the largest growers of mint in this state. He began production on an area of previously uncultivated muck soil. He was forced to borrow money to initiate his enterprise. At present he has 5000 acres of soil under cultivation using the most modern equipment and the latest agricultural technics. His experience demonstrates the possibilities, when mint oil is mixed with intelligence, resourcefulness, and energy.

Mentha piperita is susceptible to a number of diseases. Wilt caused by *Verticillium albo-atrum* R & B is by far the most serious disease of *Mentha piperita*. The attack of this fungus is by way of the vascular system of the host so that conduction is affected disastrously. However, the plant does not become flaccid as is observed with most of the wilts. The leaves near the terminal portion of affected plants are dwarfed and exhibit a characteristic bronze color. Affected plants may not die, but they become seriously dwarfed. This dwarfing may curtail the crop sufficiently so that returns measured in pounds of oil is reduced below the margin of profit. Peppermint, it must be remembered is an expensive crop to raise and process. Nelson (10) reported this Verticillium hadromycosis as occurring in Michigan in 1924. Baines was the first to report the disease in Indiana in 1940. It is most probable that the disease antedated its discovery in both states by several years. The disease spread with great rapidity in Michigan until at the present time there are but few fields in that state in which the hadromycosis is not present. History has repeated the Michigan experience in Indiana. The elapsed time in Indiana has not been sufficiently great for our growers to feel the full devastating effects recorded in Michigan mint history. The peppermint acreage in Clinton County, Michigan dropped from 5,815 in 1935 to 1,873 in 1948. Production in pounds of oil for that county dropped from 228,465 pounds in 1935 to 28,941 pounds in 1948. The yield per acre in Clinton County dropped from 39.4 lbs. in 1935 to 15.4 lbs in 1948. Verticillium hadromycosis is almost one hundred percent responsible for the decreases recorded. The story of failing mint production in Clinton County has been repeated in every other mint producing county in Michigan; and is being repeated in the muck areas of Northern Indiana. The mint acreage in Indiana has not actually been decreased to date, as we still have new and uninfected areas being brought into cultivation. The actual presence of Verticillium wilt was not proved in the Northwest until this year, 1951. Nelson indicated a number of years ago that he had found the wilt in certain areas of the Northwest but he based his observations on symptoms which is inconclusive.

Dr. Johnson of my staff was sent to Washington and Oregon in 1949 to search for the causal organism. He visited all parts of the two states where mint is grown and cultured reported and suspected plants. The culture method is the only exact method of determining the presence of the organism. His cultures were all negative and he concluded that in 1949 the disease was not present in the northwest. However, this summer the organism was cultured from diseased plants and the fungus was identified as *Verticillium albo-atrum* in my laboratory. There is now no doubt of its presence in the Pacific coast states. It is possible that climatic or soil conditions there may prevent its rapid spread.

Users of peppermint oil, particularly the manufacturers of chewing gum are confronted with the gloomy prospect of having to carry on without their most satisfactory flavoring product. This will mean a huge financial loss to such companies until they can educate the public to buy their gum with new, and possibly inferior flavors. The loss to the farmers in these areas is obvious. The loss of an industry to this state can not pass without unpleasant repercussions.

Control of Verticillium hadromycosis is difficult. Resistant varieties so useful in circumventing many diseases is not possible because of the high degree of sterility in *Mentha piperita*. My laboratory has been heavily subsidized by The Beechnut Packing Co. for the purpose of finding a basis for control of the disease. I have assigned a research team of nine members to the project. Our lines of attack have included the production, by heat, of disease resistant planting stocks. This Verticillium produces sclerotia and these bodies may be the means both of the spread and of maintaining the continuity of the fungus from season to season. To date, little is known concerning the circumstances under which the sclerotia are formed, or how, or when, they germinate. We don't know how resistant they are to drying, cold, chemicals, etc. We are making an intensive study of these sclerotia. We are investigating how the fungus responds as a whole to various soil nutrients; we are interested particularly in the response to the so-called minor elements, to pH in the soil, and to soil moisture conditions. We are making a study of the possible inhibition of Verticillium by other soil organisms. We have studied the host range of *Verticillium albo-atrum* and have found that the strain which attacks peppermint is quite specific. We are investigating the mode of entrance of the fungus into the host, and the rate, and manner of spread within the mint plant. We are hoping that the answers to these questions will give us clues as to control, and will contribute to saving *Mentha piperita* and its valuable essential oil as an agricultural industry for the state of Indiana.

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MATHEMATICS

Chairman: V. Hlavaty, Indiana University

E. Hopf, Indiana University, was elected chairman for 1952.

ABSTRACTS

Remarks on a theorem of Hajós. W. Gustin, Indiana University.— In 1942 the Hungarian mathematician Hajós proved a famous conjecture of Minkowski by means of a new theorem concerning finite abelian groups. We shall discuss this group—theoretic result of Hajós and propose some problems suggested by it.

A remark on the unified theory of special functions. M. Brent Haslam, Indiana University.— Truesdell's theory of special functions is based on the properties of the solutions of the differentio-difference equation

$$F(z, lc + 1) = \frac{\partial F(z, \alpha)}{\partial z} \tag{1}$$

In this note we consider the solutions of (1) which also satisfy a second order differential equations

$$\frac{\partial^2 F(z, \alpha)}{\partial z^2} + P(z, \alpha) \frac{\partial F(z, \alpha)}{\partial z} + Q(z, \alpha) \overset{0}{F}(z, \alpha) = 0 \tag{2}$$

Necessary and sufficient conditions that solutions of (2) satisfy (1) are found. Particular sets of equations (2) are considered and the sets in which $P(z, \alpha)$ and $Q(z, \alpha)$ are entire functions of α, and such that all of their solutions satisfy (1) for proper initial values are exhaustively enumerated.

Lie derivative for (V_m) in V_n. V. Hlavaty, Indiana University.— The notion of the Lie derivative in V_n is extended in such a way that it may be used for a (V_m) in V_n.

A mathematical problem of hydrodynamics. E. Hopf, Indiana University.—The problem deals with the 'integrals in the large" of the Euler equations of ideal fluid flow and it has to do with a fundamental difference between flows in two and three dimensions.

Sampling distribution of Gini's mean difference when the population is exponential. Paul Irick, Purdue University.—Let the variability in a sample of n independent x values be measured by the statistic

$\Delta = \Sigma \mid x_i - x_j \mid / n^2$ where x has the frequency function $f(x) = e^{-x/\sigma} / \sigma$, $0 < x < \infty$. Then a certain general method is used to derive the sampling distribution of Δ. The probability density function for Δ is given by the expression

$$\frac{n^2}{2\sigma(n-1)!} \sum_{j=1}^{n-1} (-1)^{n-1+j} \binom{n-1}{j} j^{n-2} e^{-n^2\Delta/2j\sigma}.$$

Although this particular example is of minor importance, the method of derivation will apply to the determination of many sampling distributions for statistics which measure dispersion.

On limit solutions of the complete equations of hydrodynamics. D. NEAD, Indiana University.—Suppose we have a sequence of solution systems of the complete equations of hydrodynamics (viscosity and thermal conductivity not zero) converging almost everywhere in a bounded open region R. Suppose further that along the sequence (1) viscosity and thermal conductivity approach zero; (2) the individual sequences composing the sequence of solution systems are (absolutely) uniformly bounded in R; (3) the density and temperature sequences are bounded uniformly away from zero in R. Then the limit system of the sequence (where sufficiently smooth) satisfies the system of equations which are obtained from the complete equations by setting viscosity and thermal conductivity equal to zero.

The probability that an arbitrary set of r positive integers be relatively prime. W. M. PEREL, Indiana University.—We define $P_r(N)$ to to be the number of ordered sets of the form $(X_1, X_2 \ldots X_r)$ such that

a) the Xv are positive integers satisfying $1 \leqslant Xv \leqslant N$, N a fixed integer

b) g.c.d. $(X_1 \ldots X_r) = 1$, for each set.

The probability that an arbitrary set of r integers, all $\leqslant N$, be relatively prime is $\dfrac{P_r(N)}{N^r}$

The solution of the problem is obtained by passing to the limit in the above. The result is $\dfrac{1}{\zeta(r)}$.

Continuous heating of a hollow cylinder. E. A. TRABANT and W. D. WOOD, Purdue University.—Consider a hollow cylinder whose outer surface $r = b$ is thermally insulated with heat being applied continuously at the inner surface $r = a$ according to the quadratic law $q(t) = e + ft + gt^2$. If the inner surface is assumed thermally insulated after an instantaneous source of heat, then, using some results of G. Comenetz, the temperature is found to be

$$\theta(r,t) = F_0(et + \frac{ft^2}{2} + \frac{gt^3}{3}) + P(r) + tQ(r) + t^2R(r)$$

$$- \frac{\pi}{\rho c} \sum_{\eta=1}^{\infty} \frac{e^{-\alpha\beta^2\eta t}}{\alpha} F\eta(r) \left(\frac{e}{\alpha\beta^2\eta} - \frac{f}{\alpha^2\beta^4\eta} + \frac{2g}{\alpha^3\beta^6\eta} \right)$$

where $$P(r) = \frac{\pi}{\rho c \alpha} \sum_{\eta=1}^{\infty} \left(\frac{e}{\beta^2\eta} - \frac{f}{\alpha\beta^4\eta} + \frac{2g}{\alpha^2\beta^6\eta} \right) F\eta(r)$$

$$Q(r) = \frac{\pi}{\rho c \alpha} \sum_{\eta=1}^{\infty} \left(\frac{f}{\beta^2\eta} - \frac{2g}{\alpha\beta^4\eta} \right) F\eta(r)$$

$$R(r) = \frac{\pi}{\rho c \alpha} \sum_{\eta=1}^{\infty} \frac{F\eta(r)}{\beta^2\eta}$$

with βn the successive positive roots of

$$J_1(a\beta)\, Y_1(b\beta) - Y_1(a\beta)\, J_1(b\beta) = 0$$

and where

$$Fo = \frac{2a}{\rho c(b^2 - a^2)}$$

$$F\eta(r) = \frac{\beta\eta\, J_1^2(b\beta\eta)\, [J_1(a\beta\eta)\, Y_0(r\beta\eta) - Y_1(a\beta\eta)\, J_0(r\beta\eta)]}{J_1^2(a\beta\eta) - J_1^2(b\beta\eta)}$$

For values of t sufficiently large it can be shown that the first four terms of $\theta(r,t)$ must satisfy the heat equation with appropriate boundary conditions. Analysis of this situation reveals that P, Q and R may be written as finite expressions. Finite summation formulas for these particular series of Bessel functions are thus obtained.

Severe pure shear of an elastic body. C. TRUESDELL, Indiana University.—While the general theory of large strain of a purely elastic body was formulated a century ago, it is only in the past three years that general solutions, valid for any form of strain energy, have been obtained by Rivlin. Rivlin has shown that in order to produce a state of simple shear, shearing forces alone are insufficient: normal tractions, ultimately proportional to the square of the angle of shear, must be supplied also. In the present note a state of pure shear resulting from following one simple shear by another in a perpendicular plane is discussed. It is shown that in addition to forces of the type necessary to produce each simple shear separately, a normal force of interaction, ultimately proportional to the product of the two shear angles, must be supplied.

Anti-mathematical propaganda in textbooks. GEORGE WHAPLES, Indiana University.—Every mathematics text offers itself as a solution to the metamathematical research problem of how best to present its material under given restrictions on the assumptions and on the complications permitted in the proofs. Some high school and college texts

are criticized first from this mathematical point of view and then according to the reasonableness of their demands on the pupil and their probable effectiveness as judged by educational psychology. Sections of them which are deficient on all three of these standards are called antimathematical propaganda. Examples are given; I have made an effort to confine myself to new ones.

PHYSICS

Chairman: C. HIRE, Indiana University

C. M. Zieman, Wabash College, was elected chairman for 1952.

ABSTRACTS

Design of a sensitive dew-point instrument. MARVIN ADELBERG, J. E. BROCK and Y. TOULOUKIAN, Purdue University.— The design and construction of a sensitive dew-point instrument is described. The principle of operation is simple and basic, and relatively small samples of air are required.

Essentially the meter consists of a temperature controlled gold plated condensing surface, the temperature of which is measured by three thermocouples embedded just beneath its surface. Dew formation is detected by a balanced photocell arrangement, sensitive to light reflected from the condensing surface.

New terms in the spectrum of germanium (Ge I). K. L. ANDREW and K. W. MEISSNER, Purdue University.—By means of a quartz arc lamp employing electrodes of pure germanium which were covered with pure germanium dioxide it was possible to excite about 150 new germanium lines between 10460 A and 4735 A. The wave lengths of these lines were measured with a 30 foot concave grating and partially with a Perot-Fabry interferometer. These measurements permitted several contributions to the term analysis of Ge I. Of special interest is the appearance of a group of lines which indicates the excitation of an f-electron.

Electronic states in crystals under large overall perturbations[1]. PAULA FEUER and HUBERT M. JAMES, Purdue University.—Solutions of the three-dimensional Schroedinger equation are considered for a periodic potential modified by a perturbing potential. A method of Slater[2] has been modified and used to develop the theory of large overall perturbations, such that the energy lies close to one permitted band in one region of the crystal and close to a second permitted band in another. The solution of the perturbed periodic Schroedinger equation is expressed as

$$\psi = \Sigma_k [\phi_1 (r_k)\, a_1 (r - r_k) + \phi_2 (r_k)\, a_2 (r - r_k)]$$

where $a_1(r - r_k)$ and $a_2(r - r_k)$ are functions localized about the kth atom of the crystal, appropriate to the first and second permitted bands, respectively. Difference equations are derived for the coefficients ϕ_1

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[1] Work supported in part by the Signal Corps.

[2] J. C. Slater, Phys. Rev. **76**, 1952 (1949)

and ϕ_2. The theory has been applied to a one-dimensional crystal in a uniform electric field, using the narrow band approximation; an expression has been obtained for the probability for an electron to cross a forbidden energy band.

Approximate treatment of order disorder transitions in the triangular Ising lattice. L. FOSDICK and H. M. JAMES, Purdue University.—Last year we reported on a new approximate treatment of order-disorder transitions in an Ising lattice. The method was then applied to a two-dimensional square array[1]. This method has now been applied to a triangular array, with similar results. The Curie Point is in good agreement with the exact result of Wannier, the error being about 8%. The triangular lattice shows a finite jump in the specific heat at the Curie Point as in the case of the square lattice. The large specific heat jump indicates that the approximation gives a relatively good representation of the behavior of the system in the neighborhood of the Curie Point.

Calculations have been started on the hexagonal lattice. The Curie Point given by this method is in error by only 5.5%.

Range-energy relations for α-particles and deuterons in the Kodak NTB emulsions.[2] O. GAILAR and L. SEIDLITZ, Purdue University.—The range-energy relations for α-particles and deuterons in Kodak NTB plates, emulsion No. 434,313-9 (100μ), have been determined. The α-particles from Th and Po were utilized for energies below 9 Mev, a camera having been constructed for exposing the plates to these radiations in vacuum. In addition, plates were soaked in a solution of $Th(NO_3)_2$ in alcohol and were developed at the end of three weeks, after being rapidly dried. For energies between 6 and 18 Mev, α-particles from the Purdue Cyclotron were used. Their energy was both measured and varied by a rotating Al-foil holder. After being scattered through an angle of 90° by a 0.0001 inch gold foil, the particles impinged on an NTB plate at an angle of 5°. The same method was used for deuterons with energies between 2 and 9 Mev. The results agree with those of Lattes, Fowler and Cuer[3] for Ilford plates, but indicate a higher stopping power than those of Richards et al[4] for NTA plates, which may be due to different humidity conditions. Since there may be small differences in the stopping power of different batches of emulsion, the camera will be used to calibrate NTB plates with the other emulsion numbers.

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[1] Later calculations showed a finite specific heat jump at the Curie Point rather than an infinite specific heat jump as reported.

[2] Supported by the Atomic Energy Commission and Eastman Kodak Fellowships.

[3] Lattes, C. M. G., P. H. Fowler and P. Cuer, Proc. Phys. Soc. (London) **59**:883 (1947).

[4] Richards, H. T., V. R. Johnson, F. Ajzenberg and M. J. W. Laubenstein, Phys. Rev. **83**:994 (1951).

Radiations from Ge^{69}. CHARLES M. HUDDLESTON and ALAN B. SMITH, —The radiations from Ge^{69} (39.6h) have been studied with the help of a magnetic lens spectrometer. Gamma-rays of energies 0.090, 0.388, 0.576, 0.870, 1.12, 1.34, and 1.61 Mev have been found. The positron spectrum is complex and can be analyzed into three groups of end point energies 1.215 (88%), 0.610 (10%), and 0.220 (2%) Mev. Coincidence studies have also been made. A tentative energy level scheme is presented.

Electrical analog circuits as applied to heat conduction problems. E. O. P. KLEIN, J. R. EATON, and Y. S. TOULOUKIAN, Purdue University. —The solution of some problems involving distributed parameter systems is possible only through the use of approximation methods. One such method makes use of electrical analog circuits.

The mathematics suggests, for example, that one-dimensional, transient, heat-conduction problems can be solved by using a properly designed analogous distributed-parameter electrical transmission cable. However, in the application of electrical analogs to the more complex heat flow problems, analogous distributed-parameter electrical systems are not possible; and the lumping procedure, similar in principle to the artificial line, must be used.

The lumping of parameters of a distributed-parameter system introduces what might be called a lumping error; and thus, only an approximate solution of the problem is possible.

By comparing the results obtained analytically for a given distributed-parameter system, with the results, also obtained analytically, from a lumped-parameter representation of the distributed-parameter system, it can be seen that the accuracy of analog results is a function of the number of lumped section used in the analog representation, the relative position of the point in question, and of time. The results obtained from an experimental study, using similar networks, can not be expected to be more accurate than the limiting accuracy indicated by the analytical comparison of results.

Metastable atoms in rare gases. K. W. MEISSNER and W. F. MILLER, Purdue University.—Irradiation of a glow discharge in pure helium or neon with a second source containing the same gas raises the Voltage-current characteristic of the irradiated discharge, as was shown by K. W. Meissner and R. M. Russell. The present investigation confirms their results and shows that the same effect is present in the rare gases argon, krypton, and xenon. The effect is much greater for argon than for the other gases. By means of filters it could be shown that for helium the entire effect is due to irradiation with the strongly absorbed wave length 20582 A, whereas the other strongly absorbed wave length 10830 A produces no detectable effect.

These results can be explained on the basis of the role of metastable atoms in the glow discharge. In all rare gases, irradiation with strongly absorbed radiation diminishes the concentration of metastable atoms and removes them as a source of secondary ionization. The

strong effect obtained for argon is explained by the long mean life of metastable argon atoms. The filter experiments carried out with helium can be understood by considering the possible transitions in excited helium atoms. Absorption of the 10830 A radiation raises the absorbing metastable helium atom to a state from which it can not return to the normal state. They return to the former metastable state and remain a source of secondary ionization. Absorption of the 20582 A line leads to an excited state from which the atom can return to the ground state and become ineffective as a source of secondary ionization.

Total cross sections of heavy nuclei for fast neutrons[1]. D. W. MILLER,[2] C. K. BOCKELMAN, and R. K. ADAIR, University of Wisconsin.—The total cross sections of twenty-three heavy elements for fast neutrons were determined as a function of neutron energy from 0.05 to 3.2 Mev. Neutrons were obtained by bombarding thin lithium or zirconium-tritium targets with protons accelerated by the Wisconsin electrostatic generator. The elements investigated ranged in mass from iron to bismuth, including nine elements consisting primarily of nuclei with closed shells in neutrons. It was found that the observed total cross sections of a majority of the elements investigated do not agree with the predictions of the continuum theory formulated by Feshbach, Peaslee, and Weisskopf. A very broad maximum appears in the total cross sections of thirteen of the elements studied. This maximum appears to move to higher neutron energies with increasing mass number.

How a fever thermometer works. BRADFORD NOYES, Butler University.—Many physicists have a somewhat hazy idea of the manner in which a maximum registering (clinical) thermometer operates. The idea of surface tension and the degradation of energy may be illustrated by such a thermometer. The aging of glass and the strains left after working will be discussed and illustrated.

The angular correlation of the Cd^{114} gamma rays. ROLF M. STEFFEN, Purdue University.—According to recent measurements, the 72 sec ground state of In^{114} decays not only by β^--emission into Sn^{114} but also by K-capture and β^+-emission into an excited state of Cd^{114} from which two successively emitted gamma rays of 0.548 and 0.615 Mev energy lead to the ground state. A very weak gamma ray of 1.26 Mev quantum energy has been interpreted as due to a cross-over transition.

By measuring the angular correlation of the two successively emitted gamma rays the angular momenta of the two excited levels of Cd^{114} have been investigated. The measured points follow, within experimental error, the angular correlation function $f(\Theta) = 1 + 0.125 \cos^2 \Theta + 0.042 \cos^4 \Theta$ which is characteristic for two quadrupole transitions between states of angular momenta of 4, 2 and 0. The angular momentum 4 of the 1.26 Mev level strongly supports the assumption

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[1] Work supported by the AEC and the Wisconsin Alumni Research Foundation.

[2] AEC predoctoral fellow; now at Indiana University.

that this level is reached directly from the 50-d isomer. The ft value, 3×10^8 sec, of this K-decay suggests a first forbidden transition involving a spin change of one and parity change.

The dielectric constant of dry air at wavelength 3.2 cm. CLAYTON M. ZIEMAN, Wabash College.—A cavity comparison method was used to make 50 measurements of the dielectric constant of dry air at a wave length of approximately 3.2 cm. The result, corrected for permeability, and reduced to S. T. P., is

$$(\epsilon_0 - 1) \times 10^4 = 5.754 \pm 0.021.$$

PSYCHOLOGY

Chairman: G. A. ZIRKLE, Hanover College

L. M. Baker, Purdue University, was elected chairman for 1952

ABSTRACTS

Changes in personnel questionnaire responses as a function of instructions. N. FRIEDMAN and E. J. MCCORMICK, Purdue University.—The purpose of the investigation was that of analyzing the stability of responses in various situations to items on the Personnel Questionnaire. The four parts of the test include items somewhat comparable to those on typical personality and interest questionnaires.

The test was administered to three groups of students in the following test-retest situations:

A. Testing and retesting 40 students in a clinical situation.

B. Testing 35 students in a clinical situation and two days later in a simulated job application situation.

C. Testing 22 students in two different simulated job application situations.

Finally, the responses of students to items in one of the simulated job application situations were compared with those of actual applicants for the same job.

The results of the above three test-retest situations were as follows:

A. All parts of the test but Part I (Personal Interests) demonstrated adequate reliability.

B. Responses to approximately 50 per cent of the items were falsified. Part IV (Personal Beliefs) showed a significantly smaller per cent of falsified items than did the other parts.

C. One third of the items were answered differently in the two simulated job application procedures; the differences were most marked for Part II (Work Preferences) and least marked for Part IV (Personal Beliefs).

Finally, it was found that students could accurately simulate the job application situation.

Training and experience of high school teachers of psychology, together with teacher and pupil attitudes toward the course. T. L. ENGLE, Indiana University, Fort Wayne Center.—Psychology is taught in 34 states but only nine states have specific licensing requirements for teachers of psychology. Questionnaires concerning training and experience were sent to 453 teachers of psychology. Replies were received

from 147 teachers in 26 states. Teachers in 97 schools in 24 states administered a rating scale to 2783 pupils.

The mean number of years of college training is 5.04 but the training is primarily in social science and education rather than in psychology, some teachers of psychology reporting no training in psychology.

No teachers limit their work to the teaching of psychology, the most common area for other teaching being the social sciences. Slightly over half serve as superintendents, principals, or directors of guidance.

Psychology is taught as a one-semester course in 64.8 per cent of the high schools, but 68.3 per cent of the teachers and 87.0 per cent of the pupils think it should be at least a two-semester course.

Both teachers and pupils rate psychology as contributing more than most subjects to meeting objectives of secondary education, the greatest contribution being to co-operation and family-life. Pupils in two-semester courses rate psychology higher in meeting objectives than do pupils in one-semester courses, the significance ratio for the difference being 8.15.

An investigation into the effects of neutral wet pack therapy. DAVID GOODENOUGH, Logansport State Hospital.—The reactions of one negro and fourteen white psychotic male patients to neutral-wet-pack hydrotherapy were studied intensively over a period of five months. Verbalizations, pulse rate, breathing rate and general activity were recorded while patients underwent treatment. Group comparisons were made to determine which factors were most important in the "sedative effectiveness" of this treatment. Ranked global activity as an overall measure, and pulse rate as a single index of activity, were treated statistically by analysis of variance procedures.

The difference in amount of mean activity between patients with favorable attitudes toward "hydro" and patients with unfavorable attitudes was statistically significant (at better than the one per cent level) no matter which variable was used in the analysis. Individual differences in the "sedative effectiveness" of neutral-wet-pack therapy were clearly indicated, greater variability in reaction being charactristic of those patients who had expressed a dislike for treatment. A consistent downward trend in pulse rate was apparent in patients with favorable attitudes, and this trend was shown to be adequately described by a parabolic curve.

There was no evidence of reliable differences in reaction between patients accustomed to pack and those who were experiencing this form of treatment for the first time. Nor was there a statistically significant difference discernible between the "sedative effectiveness" of wet-pack as opposed to dry-pack treatment. A slight, irregular, downward trend in pulse rate was noticeable in the wet-pack records of patients with favorable attitudes but trends, if they existed at all, were obscured in the dry-pack records. Suggestions for future research, in which the influence of factors such as attitude is more properly controlled, are offered.

Drive intensity as a cue in discrimination training. EDITH D. NEIMARK, Indiana University.—Hull has postulated that drive serves a dual function as stimulus and as a determiner of general activity. Several studies have been attempted to demonstrate the stimulus value of drive by establishing a discrimination based upon two qualitatively different drives, or upon two intensities of the same drive. The present study has attempted to demonstrate that stimulus intensity can function as a discriminative stimulus in a situation where all other stimuli are maintained constant. Two groups of seven animals each were trained to press a bar for water reinforcement in a standard Skinner box situation. The animals of Group A received continuous reinforcement for responses emitted after 22 hours of water deprivation; but were not reinforced for responding after 2 hours of deprivation. For Group B, conditions were reversed. The training series for both groups consisted of sixteen ten-minute periods of training under each drive condition. During the first three minutes of each training period, no responses were reinforced; after this test interval the discrimination training appropriate to the drive level was given. After training, each group received four ten-minute extinction periods under each drive level, varied in a random sequence. An analysis of rate of response for initial three minute intervals reveals significant differences between two drive levels in any one group; but it provides no clear-cut evidence of discrimination. Rate of response during extinction, however, indicates that a discrimination has been formed.

Physiological correlates of a defense mechanism. G. HUGH RUSSELL, Purdue University.—Experimental methods, along with laboratory instruments, were used in testing hypotheses derived from psychoanalytic theory concerning the interaction of a defense mechanism and the expression of anxiety. Two groups of experimental subjects were selected for testing on the basis of their achieving relatively high or low scores on measures of their need for the defense in question. Hypotheses were tested by comparing these groups on the measures of behavioral manifestation of the defense and anxiety present when the defense is threatened. No significant differences between groups were found on either of the measures. The data suggested an inverse relationship between the use of the defense and the arousal of anxiety for that group having the greater need for the defense. The usefulness of instrumental approaches in research on psychoanalytic theory is discussed and suggestions are made for future research.

Alternation of responses as a function of hunger drive level in a two-choice maze situation. MAX S. SCHOEFFLER and JAMES STRAUGHAN, Indiana University.—In 1934, Elliot demonstrated that rats tended toward greater stereotyping of behavior when they were under a greater degree of food deprivation. In his five choice problem, there was however no control over the time interval between choice and reinforcement. The present study was designed to investigate the alternation variable, when the time between choice and reward was kept constant for high and low deprivation groups.

Sixteen rats were randomly divided into two groups; one group being deprived of food for two hours, the other for 22 hours. Both groups were trained for 32 random forced trials, and were then allowed free choices for 51 trials which constituted the test runs. All trials were performed on a 16 inch runway, the end of which was partitioned into two compartments. In this way, the choice point was no more than two inches from the point of reinforcement. A 44 mg. food pellet was used as reinforcement on each run, both compartments being constantly available throughout the test trials.

An analysis of the mean per cent of alternation of the two groups, showed that the two groups differed at the five per cent level of significance, the 22 hour group alternating less than chance.

The effect of angle of inclination upon alternation behavior in the rat. EDWARD J. THWING and SIDNEY HELLYER, Indiana University.—Purpose: to test certain predictions from reactive inhibition theory with respect to alternation behavior.

First test period: Half the trials were given with the runways in a horizontal position and half with the runways leading from the choice point inclined at a 45 degree angle.

Second test period: Half the trials were given with one runway horizontal and the other inclined. For the other trials the conditions were reversed.

Results: First test period. No significant difference was found in frequency of alternation on the inclined as compared to the horizontal runways.

Second test period. There was a significant preference for the level as compared to the inclined runway.

Discussion: If we can assume more effort per unit time was necessary to traverse the inclined runways than the horizontal runways and if the concept of reactive inhibition accounts for alternation behavior, then we would predict a greater frequency of alternation when the runways were inclined. The results of this study do not confirm this prediction.

ZOOLOGY

Chairman: C. J. GOODNIGHT, Purdue University

F. R. Elliott, Valparaiso University, was elected chairman for 1952

ABSTRACTS

Preliminary laboratory report concerning the effect of colchicine on development in *Drosophila melanogaster*. R. L. BELL, Purdue University.—An attempt was made to duplicate the tetraploid character produced by the colchicine-treatment of plants in *Drosophila melanogaster*. The Drosophila were treated by adding the colchicine (in a solution) to the culture media. No macroscopic evidences of tetraploid individuals were apparent. A concentration of active ingredients in the order of one part/million parts of media was sufficiently toxic to prevent the development of an adult F_3 generation. Toxicity was found to be a function of both concentration and the stage of the individual's development.

Geographical distribution of the land snails of Indiana. CLINTON J. BUSHEY, Taylor University, Upland, Indiana.—Very little work has been done on the geographical distribution of land snails in Indiana. Collections have been somewhat concentrated in a few locations but this has been more or less by chance. Dr. Call, in 1900, presented a comprehensive list from the state with descriptions. Cohn and Kemp in 1929 published a paper on the land snails found in Turkey Run State Park. Goodrich and Van der Schalie put out in 1944 a revision of the Mollusca of Indiana. Dr. Pillsbry in his great Monograph on the Land Snails of North America includes many snails from Indiana, but none of these make any determined attempt to locate where in Indiana these snails are found.

The project in mind is to collect from as many sections of the state as possible and make the record available. All available literature is being studied as possible sources. The author is anxious to supplement from any source possible and would appreciate receiving land snails from anybody in the state. Include location data when forwarding specimens.

Methods for the quantitative estimation of cell densities in sectioned tissues. D. T. CHALKLEY, University of Notre Dame.—Cell and nuclear densities determined by the usual grid method are subject to increasing error as the cell diameter/section thickness ratio increases. This error can be reduced for tissues with nuclei lying parallel to the section plane by using a grid whose parallels are separated by an

interval equal to the section thickness. The nuclear density d is found by:

$$d = (d_o^3 \times d_n^2)^{1/5}$$

Where d_o is the number of nuclei lying within the grid limits and d_n is the number of these nuclei which do not cross the grid parallels. In epithelia the area a covered by the average cell can be approximated from the formula:

$$a = \frac{\frac{180}{4nc^2 \tan n}}{\pi^2}$$

Where n is the average number of cells in contact with a given cell and c is the mean chord of the cell cross section in a plane parallel to an epithelial surface. Densities are computed for unit area of the cross section plane.

A technique for growing hydroids in the laboratory. SEARS CROWELL, Indiana University.—A small piece of a hydroid colony is tied by a thread to a glass slide. Growing stolons attach to the slide and the thread is removed. Slides are kept in well oxygenated, cool, moving water. Specimens are fed once or twice a day with newly hatched brine shrimp (*Artemia*). Under these conditions growth is rapid, specimens appear healthy, and observations can be made easily. The method has been used for the fresh water hydroid *Cordylophora*, and for *Hydractinia*, *Podocoryne*, and *Campanularia*. —Demonstration.

Food-web dynamics in a pond. CLARENCE F. DINEEN, Notre Dame University.—A small pond located in Ramsey County, Minnesota was studied for two years. Physical records, chemical analyses, and quantitative collections of planktonic and benthic organisms were made weekly except during the winter. The annual production of the higher aquatic plants was determined.

The trophic relationships of the organisms in the pond community formed a complex food web. The organisms were separated into the following major food groups: 1) phytoplankters; 2) zooplankters; 3) browsers; 4) predators on the plankton; 5) benthic predators; 6) swimming predators; 7) filamentous algae, duckweed, and pondweed. The ash-free dry weight of each food group was determined. The day weights were converted to calorific values.

The food groups formed three trophic levels; namely: the producers (chlorophyll-bearing plants), primary consumers, and secondary consumers. The productivity and the biological efficiency of the three trophic levels were determined. The biological efficiency increased from the producer level to the top consumer level while the rate of production decreased from the producer level to the top consumer level.

The action of x-rays on mitotic activity and leucocyte infiltration in regenerating urodele limbs. WALTER J. FIMIAN, JR., University of Notre Dame.—Forelimbs of the adult newt fail to regenerate after exposure to

x-ray doses of the order of 15,000 r. Comparisons of the patterns of distribution of mitoses in normal and partially irradiated limbs indicate that the initial burst of mitotic activity in the connective tissues of the stump is markedly suppressed in the irradiated areas. Suppression of mitotic activity in the epidermal tissues is only temporary. The number of leucocytes present in the irradiated limbs is much lower than in the controls.

The origin of the Phalangodidae (Phalangida) of the United States. CLARENCE J. GOODNIGHT, Purdue University.—Phalangodids are small tropical phalangids that are world wide in distribution. In the United States, they are limited to the southern states although one species extends as far north as Southern Indiana and Ohio. From the structure and distribution of them, it is apparent that North American species are derived from the Mexican forms. Their invasion into more northern areas must have been at a comparatively recent date as evidenced by the paucity of species and the restricted localities in which they live. From a study of species, it is probable that the Ozark plateau and the Appalachian highlands were secondary centers of differentiation and distribution of forms. Another group of Phalangodid species migrated to the west and are now found in Texas, Arizona, and on the west coast. Still another genus in this large family is found in southern Florida. The species here is a very recent invader from Cuba. So recent is its invasion that it is only subspecifically different from the Cuban form.

Oxygen consumption and development of *Stagnicola reflexa*. P. LEONARD KNIGHT, JR., University of Notre Dame.—The time for the complete embryonic development of the snail, *Stagnicola reflexa* (Say, 1821) has been determined as 223.5 ± 4 hours at temperatures ranging between 18 and 21°C.

The eggs are deposited in capsules, which in turn are surrounded by a gelatinous matrix. The capsules in a single clutch have been found to vary in length and width. The volume of the clutch depends on at least three factors 1) age, 2) number of capsules and 3) size.

Warburg respirometers, maintained at 25°C., have been used to determine the oxygen consumption of ten stages (single cell to and including the pre-hatch). A linear rate of increase in the amount of oxygen consumed has been observed after 68 hours of development. The total amount of oxygen consumed by a single embyro during its development has been determined to be 8.9933 C.mm. (approx.). It is believed that ciliary activity and muscular movement have a significant effect upon the amount of oxygen consumed by the various stages.

The problem of pH change in the Warburg apparatus. LAWRENCE H. MONACO, University of Notre Dame.—Failure to consider loss of KOH by possible diffusion through surface films in the center well of the conventional Warburg Constant Volume respirometer flask has made the accuracy of much of the previous research questionable. Exhaustive tests in our laboratory have shown that "creeping" or splash-

ing of alkali from the center well into the experimental fluid occurs despite recommended precautions as to center well volume, the use of "KOH papers", greasing the center well rim, and shaking speeds and amplitudes.

Using two drops of phenolphthalein in 3 cc. of distilled water as the experimental fluid, the following methods were used in an attempt to eliminate the error due to KOH splashing: (1) adding a known volume of 10% KOH, ranging from 0.2 ml. to 0.6 ml., to the center well; (2) greasing the top of the center well with various commercial greases; (3) placing a few strips of filter paper in the center well; and (4) controlling the speed and amplitude of shaking after attaching the manometer. It was found that in spite of all these precautionary measures a pH change occurred as registered by the indicator.

Further work in this regard by using various ion exchangers in place of KOH is in progress.

The mental gland of *Plethodon glutinosus*. ALBERT E. REYNOLDS, DePauw University.—In adult males of the salamander *Plethodon glutinosus* the skin of the lower jaw exhibits a small circular area of thickened and relatively less pigmented skin which constitutes a "chin button" or "mental gland" that has been interpreted as being hedonic in function. In this paper a preliminary account of the histology and size relations of the gland is given.

A snail shell with a double peristome. ARTHUR L. SCHIPPER, University of Notre Dame.—A specimen of *Stagnicola reflexa* (Say) has been found, the shell of which possesses a double peristome. Extension of the original peristome was discontinued and a new peristome has been formed, the attachment being inside the older peristome. The newer portion of the shell is in contact with the older portion only at the point of original attachment and along the parietal wall of the aperture. Extension of the newer portion of the shell has placed the second peristome beyond the point reached by the first.

The Incidence of Pinworm Infection among Indiana Children with Comments on Methods of Laboratory Diagnosis[1]

William Hugh Headlee, Indiana University Medical Center

Introduction

Enterobiasis, a parasitic disease, is also known by the synonyms pinworm infection, seatworm infection, oxyuriasis, and *Oxyuris* infection. The etiological agent is *Enterobius vermicularis*, a small white nematode, or roundworm, about 1 cm. long, and tapering from the midregion toward each end, the posterior end being considerably elongated and finely pointed. The life history and general disease entity may be obtained from standard texts. We wish to emphasize that the females do not lay eggs while in the intestine, but retain them until the uteri are gravid, at which time the worms migrate from the anus and each female worm deposits some 11,000 eggs on the perianal and perineal skin. This fact was recognized by the Continental workers for some time before it was brought to the attention of workers in the United States by Headlee (4) and by Hall (3). It was emphasized that stool examination was not a reliable method of diagnosis, and that efforts at making a laboratory diagnosis must be directed toward the recovery of the eggs from the perianal region and their identification by miscroscopic examination. In only about 5 per cent of the cases of pinworm infection can ova be found in the feces of the infected individual. A specific diagnosis can be made occasionally by identification of adult worms found in the perineal region or in stool specimens (particularly after a purge), but is most usually made on the basis of eggs found by the miscroscopic examination of materials collected from the perianal skin. In recent years considerable effort has been expended to devise new methods for the recovery of pinworm ova from the perianal region, and to test the devices used in these collection methods for their relative efficacy in performing this function. Among the devices that have received considerable trial may be mentioned the N.I.H. cellophane-tipped anal swab devised by Hall (3), the Graham transparent cellulose (adhesive) tape devise (2), a modification of the same by Jacobs (8), and the glass pestel device of Shüffner and Swellengrebel (11). The literature in regard to the various methods of diagnosis has been recently reviewed by Headlee (7), Beaver (1) and others. It is the purpose of the present paper to report concerning recent experiences with one of these devices, and to comment on its efficacy in the light of experiences with other methods.

Materials and Methods

During the past year some 321 orthopaedic patients confined to the James Whitcomb Riley Hospital for Children were examined to deter-

[1] This work was supported by a grant from Burroughs Wellcome and Company (U.S.A.) Inc.

mine the incidence of pinworm infection among them. This group was chosen because the individuals of the group were usually confined to the hospital for a relatively long period, permitting repeated examinations on several consecutive days, and a more accurate determination of the actual status of pinworm infection. The Jacobs (8) modification of the Graham (2) transparent cellulose (adhesive) tape method was used to collect perianal materials from the patients. By this method a piece of cellulose (adhesive) tape is folded over the end of a tongue depressor, adhesive side out, and is held there by the operator's thumb and forefinger while it is applied to the skin in the region of the anus. Ova or other materials present on the skin will adhere to the tape. After use the tape is then smoothed out on a miscroscope slide, adhesive side down, and examined miscroscopically for ova of the pinworm. To facilitate examination of the tape a drop of toluene was placed between the slide and the tape to clear the preparation and increase visibility, as suggested by Beaver (1).

The cellulose tape devices were made up in advance of the anticipated need. Pieces of paper ¾ in. by 1 in. were stuck to the cellulose tape at the beginning of each 3 inch space as it was unrolled from the dispenser. The tape was then cut crosswise at the middle of each piece of paper, resulting in pieces of tape three inches long, each end having a non-adhesive region ½ inch long by which it could be picked up without adherence to the fingers. The piece of tape was then placed, adhesive side down, on a clean 1 in. by 3 in. glass slide and smoothed out. This tape-device was then placed in a 2¼ in. by 3½ in. Manila coin envelope until used. The tape could be readily removed from the slide to collect perianal materials, then replaced on the slide ready for examination, being replaced in the envelope for transporting to the laboratory. Each tape-device was numbered on one of the paper-tab ends, and the number was used in identification and recording. The number of the tape-device was written on the envelope, along with the name of the patient and other pertinent information.

Results

A total of 2065 examinations were done on the 321 patients studied. Of the 321 individuals examined, 128, or 39.9 per cent, were infected with the pinworm, as determined by the method used. A person was considered negative if no ova of the pinworm were found after the examination of six tape-device preparations, obtained one each on each of six successive mornings. In the present series, 73 of the 321 individuals, or 22.7 per cent, were found to be positive on the first examination. In other words, we detected about 60 per cent of the infected individuals by one examination, using the cellulose (adhesive) tape device. Several individuals were examined at daily intervals for a number of different periods to determine the course of the infection in reference to treatment, and this will be summarized in another report in the near future.

Discussion and Conclusions

Use of the cellulose (adhesive) tape device for the collection of perianal materials, which are then examined microscopically for ova, leads to the detection of a greater percentage of persons harboring the pinworm than does other devices or methods that have been used at the Indiana University Medical Center. By stool examination on a comparable group of children (5), 13, or 7.7 per cent, of 168 children in Riley Hospital were infected with the pinworm. Using the N.I.H. swab, one examination only, 39 or 16.3 per cent, of 240 children in Riley Hospital had pinworm infection (6). In the present series, with one examination, using the cellulose tape-device, 22.7 per cent of the individuals were found to be infected, but when six examinations were made on the same individual, 39.9 per cent of those examined were found to be infected. These data would seem to support the findings of Mazotti and Osorio (10), Beaver (1) and Jeffery (9) that the cellulose (adhesive) tape method of collecting perianal materials in the diagnosis of pinworm infection is substantially superior to the N.I.H. anal swab, and appears to be the most effective device yet tried.

The present findings indicate that pinworm infection is much more prevalent among Indiana children than was formerly supposed.

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Asymmetry of Chicken Thyroids[1]

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Asymmetry of paired organs in vertebrates has been reported by several authors. Etzold (2) reported that in 18 of 19 pairs of testes of the English sparrow the left gonad was larger than the right. Riddle (3, 4, 5) concluded from his observations on male pigeons that their right testis was larger than their left. He suggested, however, that the reverse was true in fowl. Breneman (1) made an analysis of the gonad weights of 1458 male White Leghorn chickens aged 5 to 140 days. He found that the left testes have a greater mean weight than the right testes throughout this age range, thus confirming Riddle's suggestion.

These observations raised the question whether a similar asymmetry might exist in other paired organs. It was, therefore, decided to weigh left and right thyroids of chickens of different ages. This paper reports the results of these measurements.

Materials and Methods

The observations reported here were made upon 248 male single comb White Leghorn chickens. The chickens were kept in battery brooders and fed a standard balanced chick ration. At time of autopsy the left and right thyroids were removed and weighed individually to the nearest mg. on a Roller-Smith torsion balance. Data were obtained from birds of the following ages: 30, 35, 40, 60, 70, 80, 85, 90, 95, 100, 120 and 125 days.

Observations and Discussion

The mean weight of the left thyroids at each age was greater than that of the rights. This is illustrated in Figure 1. The level of significance of the difference of these mean weights at each age was determined by applying the *t* test to the figures obtained by running a paired measures analysis (6). It may be seen in Table I that the *t* test gave a high level of significance for seven of the twelve ages included. There is little doubt that the test of difference would be significant at the other five ages if the size of the sample at those ages were increased.

It should be noted that there were some right thyroids which were bigger than their corresponding left thyroids. In 21% of the birds examined the right thyroids were larger than the left thyroids.

A regression line was plotted for the weight of the left thyroids against age, and likewise for the weight of the right thyroids against

[1] Contribution No. 479 from the Department of Zoology, Indiana University.

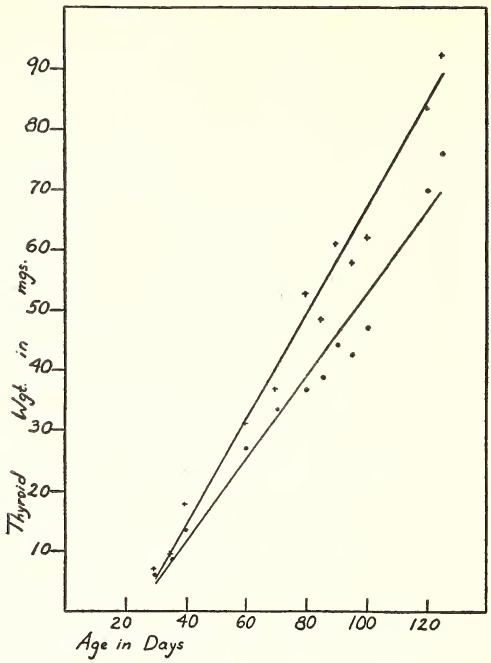

Fig. 1. Thyroid weights: Pluses represent mean weights of left thyroids. Dots represent mean weights of right thyroids. Lines represent regression lines of left and right thyroids.

age. A test between the two regression coefficients thus obtained showed that there is a significant difference (at the 1% level) in rate of growth between the left and right thyroids, the former growing at a faster rate.

In experimental work the individual organs of a pair are sometimes treated as being equivalent to each other in all respects. For example, an investigator may compare the weights of the individual glands of a pair after subjecting each to different treatments. The observations presented in this paper demonstrate that the left and right thyroids of chickens are not equivalent as regards weight and rate of growth. An error would, therefore, be introduced by considering them equal.

The reason for the observed bilateral asymmetry of chicken thyroids is not known. It might be suspected that the circulatory system is the determining factor, especially since the thyroid is one of the most highly vascularized glands in the body. However, no information is available to support this suggestion, and other possible causes can be imagined. The reversed condition of asymmetry as found on the one hand by Riddle in pigeons and on the other hand by Breneman and this author in chickens suggests the possibility of a direct but

TABLE I. Comparison of Average Weights of Left and Right Thyroids at Various Ages from 30 to 125 Days

Age	No. Animals	Average Wt. Left	Average Wt. Right	"t" test (% signif.)
30	17	7.0	6.1	6%
35	29	9.3	8.4	14%
40	16	17.6	13.4	1%
60	9	30.8	26.9	30%
70	28	36.8	33.4	11%
80	36	52.6	37.2	<1%
85	27	48.3	38.9	<1%
90	32	60.8	44.3	<1%
95	10	57.9	42.6	<1%
100	17	63.1	47.2	<1%
120	10	86.2	69.7	22%
125	17	94.2	75.9	<1%

opposite genetic determination in these two different species of birds. The resolution of this problem awaits the accumulation of further knowledge.

Summary

The left and right thyroids of 248 single comb White Leghorn male chickens aged 30 to 125 days were weighed individually on a Roller-Smith torsion balance. The average weight of the left thyroids was greater than that of the rights at all ages included. The left thyroids also had a faster rate of growth than the right thyroids. No explanation of this bilateral asymmetry is offered.

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Further Evidence for Thyroid Function in Anuran Larvae

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Preliminary observations made on the effects of 2-thiouracil on *R. clamitans* larvae (4) indicated that the thyroid gland of Anuran larvae is actively secreting early in development and that this secretion has a definite role in the growth of the organism. The present paper is an extension of the earlier work and is designed to present further evidence for the function of the larval Anuran thyroid grand.

First, it must be admitted that the earlier experiments did not conclusively demonstrate that the effects of thiouracil were due to an action of this compound resulting in suppression of thyroid function. If such a suppression actually occurs, the results obtained should be reversible by thyroxine treatment, and larvae maintained on a low dosage of thiouracil, i.e. one that would not inhibit normal metamorphosis, would not differ significantly from the controls. Second, there is the possibility that the results obtained on *R. clamitans* larvae are not applicable to other Anuran species that have a free-living larval stage. Finally, the bilateral asymmetry of the gonads of the *R. clamitans* larvae, as determined by the greater length of the left gonad compared with the right in microscopical sections, suggested that if the left gonad of the adult were found to be larger than the right, then somewhat more confidence could be placed in the differences observed between the gonad lengths of the thiouracil treated and control larvae. This situation has been reported to exist in *R. sylvatica* by Hoskins and Hoskins (1).

Materials and Methods

The larvae employed in these experiments were obtained by induced ovulation (3). Mature *R. pipiens* frogs were obtained locally from an animal dealer and the *R. clamitans* and *R. catesbiana* frogs were captured personally at Yellowood Park. Three separate groups of animals will be considered in this paper.

The first is a group of *R. pipiens* larvae reared in eight-inch finger bowls by a method previously reported (4). Two bowls served as controls while two bowls were treated with 0.030% 2-thiouracil. One group of both the control and thiouracil treated larvae were weighed on the 22nd day after fertilization. Samples of ten body weights were taken on the 35th and 40th days. On the 40th day five animals from each

[1] The author wishes to express his indebtedness to Dr. W. R. Breneman for his helpful criticisms and suggestions and to P. S. Alexander and C. J. Shellabarger who lent technical assistance in the procurement of portions of the data reported.

[2] Contribution No. 476 from the Department of Zoology, Indiana University, Bloomington, Indiana.

group were fixed in Bouin's fixative. Also on the 40th day, thyroxine treatments were begun on one bowl of the control animals by adding one cc. of a 0.0010% solution of the culture medium to make a concentration of ten gamma per liter, and the thiouracil dosage was reduced to 0.010%. On the 53rd day five animals from each group were weighed and fixed in Bouin's. Serial transverse 8 micron sections were made of the animals fixed in Bouin's and the length of the gonads was determined by counting the number of sections in which a definitive portion of the gland appeared.

The second is also a group of *R. pipiens* larvae. Fifty larvae were reared in each of two aquaria containing eight liters of aerated tap water. One group was used as a control while the other was treated with a low dosage of 2-thiouracil, 0.0075%. These animals were fed a diet of Pablum supplemented by commercial dog food. A sample of ten weights was taken on the 63rd day. On the 112th day, after approximately 50% of the animals in both groups (17 controls and 25 thiouracil treated) had undergone metamorphosis, the animals were sacrificed and the body weights of the metamorphosed animals were determined.

The third set of animals to be considered is a group of mature male frogs captured on June 2, 1951. These animals were sacrificed shortly after capture and the right and left testes of ten male *R. catesbiana* and twenty-four male *R. clamitans* were individually weighed on a torsion balance to the nearest 0.5 mg.

Results

The results obtained from the *R. pipiens* larvae reared in the finger bowls are summarized in figure 1. The mean body weights of the various groups at 53 days are: control, 118.8 mg.; thiouracil, 169.8 mg.; thyroxine, 45.0 mg. The differences between these means are significant at the 1% level when tested by the "t" test. Before 53 days there is a higher probability that the differences observed are due to sampling error. This is not surprising inasmuch as it was at about this period of ontogeny that significant differences between the thiouracil treated and control series of *R. clamitans* larvae were noted (4), and perhaps this indicates that the thyroid gland of *R. pipiens* begins to secrete somewhat later in ontogeny. The fact that thyroxine reverses the effect of thiouracil strengthens the contention that the results of thiouracil treatment are due to hypofunction of the premetamorphic Anuran thyroid gland. The level of thyroxine treatment employed in this experiment resulted in considerable metamorphic advance during the period of treatment, e.g. forelimb emergence and the beginning of tail resorption. Even more interesting than the effects of the treatments on mean body weights are the differences observed in the gonad lengths. At 53 days the mean gonad lengths of the various groups were: control, 0.772 mm.; thiouracil, 0.944 mm.; thyroxine, 0.602 mm. The difference between the thiouracil and control group is significant below the 2% level ("t" = 2.6450) and the differences be-

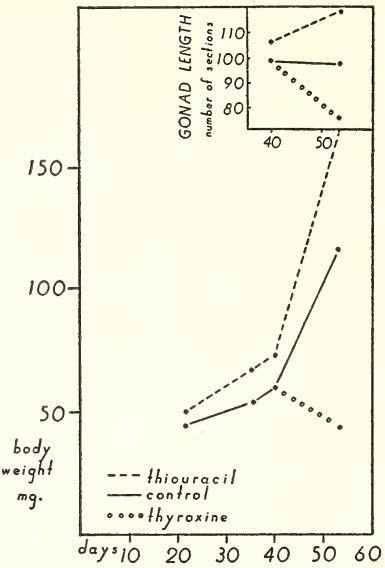

Fig. 1. Graphs showing the effects of thyroxine and 2-thiouracil on the mean body weights and gonad lengths of *R. pipiens* larvae.

tween the thyroxine and control groups are significant at the 1% level. This again shows the reversibility of the effect of thiouracil by thyroxine and indicates that the more rapid increase in the mean body weights of the thiouracil treated larvae is reflected in changes in the growth of the internal organs. It was also found that in 21 of the 25 pairs of gonads that were measured the left was longer than the right.

The results obtained from the *R. pipiens* larvae reared in aquaria were entirely negative. No significant differences were noted between animals treated with 0.0075% 2-thiouracil and the control larvae. The mean body weights of the 63 day samples were: controls, 193 mg.; thiouracil, 212 mg. The mean body weights of the metamorphosed animals were: controls, 824 mg.; thiouracil, 877 mg. These differences were not significant ("t" = 0.427 and 0.721 respectively). Even the decrease in the melanin pigment usually noticed to a variable extent in the thiouracil treated groups due to the inhibitory effect of this chemical on tyrosinase (2) was not observed, and it may be that the changes in pigment formation may serve as a crude measure of the anti-thyroid activity of a given dosage of thiouracil. However, the fact that a dosage of thiouracil insufficient to interfere with normal thyroid function does not alter larval growth also strengthens the contention that the effects of higher dosage levels are due to the action of this chemical on the thyroid gland.

The results of the individual measurements made on the right and left testes of mature male frogs were quite interesting. In 22 of the

24 pairs of *R. clamitans* testis weights the left was heavier than the right, while one showed no difference, and the remaining one showed the right to be slightly heavier. When the difference between the members of each pair is treated statistically the difference is found to be significant at the 1% level ("t" = 5.806). In the smaller sample of ten pairs of *R. catesbiana* testis weights the situation was quite similar and in only one pair was the right heavier than the left. These data suggest that difference observed in the lengths of the sectioned right and left gonads of the *R. clamitans* larvae (4) reflects a greater growth potential for the left side and also that the differences observed between the gonad lengths of the thiouracil and control larvae probably represent a real size difference.

Summary

Evidence is presented that 0.030% 2-thiouracil treatment of *R. pipiens* larvae results in a more rapid increase in body weight and gonad length than is observed in the controls. These results are reversible by thyroxine treatment. Treatment of *R. pipiens* larvae with a low dosage of thiouracil, (0.0075%), does not inhibit metamorphosis and has no significant effect on body weight. Thus, it seems likely that the effects of 0.030% thiouracil can be attributed to a hypofunction of the thyroid gland and that the thyroid secretion normally plays a role in controlling the growth of the pre-metamorphic Anuran larvae. Data are also presented that indicate that the left testis of *R. clamitans* and *R. catesbiana* frogs is usually larger than the right which strengthens the data obtained by measurements of microscopic sections of *R. clamitans* larvae in which a similar situation was observed.

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Balanoglossus and the Origin of the Vertebrate Nephros[1]

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It was in 1886, writing on "The Ancestry of the Chordates", that William Bateson (4) made the following remarks: "Upon the origin of the excretory system of vertebrates nothing can be affirmed from a study of Balanoglossus. The excretory systems of Vertebrates cannot be easily derivable from anything found in either Balanoglossus, Ascidians, or Amphioxus. The absence of any regular excretory system in these three forms may, perhaps, be correlated with the extraordinary development of their respiratory systems which may possibly assist in this function. The one fact which is derivable from the morphology of Balanoglossus, Ascidians and Amphioxus is that it is nearly certain that the excretory system of other Chordata has been developed within the group."

Observations made during the sixty-odd years since those words were written by no means invalidate them in their entirety. With excretory organs of one kind or another long since known for all three groups, the statement on "absence of any regular excretory system" obviously does not hold. But the question of evolutionary origin of the vertebrate nephros, implicit to the final remark, remains as much a puzzle today as it did then.

The structural unit of the vertebrate kidney is the nephron. While they exhibit progressively greater complexity in the evolutionary march from cyclostome to mammal, all nephrons are built to the same basic pattern: a tubule equipped with an elaborate blood supply. This tubule is invariably derived from coelomic epithelium, i.e., is mesodermal in origin, and may, although normally not, show its relation to the coelom by remaining open thereto. The blood supply consists of a filtering bed composed of a capillary tuft, or glomerulus, associated with the central or coelomic end of the tubule and a second set of capillaries surrounding the tubule proper. The distal ends of the multitudinous nephrons composing a kidney ultimately empty into a common collecting duct. This is the kind of excretory unit which appears abruptly and full-blown on the evolutionary scene, having been identified even in the oldest vertebrates known, the ostracoderms, and about whose invertebrate origins we should like to know more. Do present-day protochordates offer excretory parts suggestive of a kind which by some remodeling could have become vertebrate-like?

The tunicates are certainly not very helpful. They have been described as possessing clusters of vesicular cells usually associated with some division of the digestive tube. These range from a loose assemblage of cells in the more primitive forms through an agglomerated

[1] Contribution No. 477 from the Department of Zoology, Indiana University.

visceral mass to a large vesicular body in the Molgulidae, the most specialized of the ascidians. All are products of the vascular mesothelium and in the last instance the individual cells have fused to form the single bladder-like structure. The evidence that such bodies, whatever their makeup, are truly excretory organs is somewhat circumstantial. Most of the argument rests on the presence within the cells of crystalline masses of uric acid, although the ability of the vesicles to take up methylene blue in vitro has also been cited (Asema, 1). Even granting their excretory nature, they certainly bear no resemblance to nephrons. They thus offer just one more piece of evidence supporting the view that the tunicates are off the main line of vertebrate evolution, constituting instead a group of degenerate and specialized descendants of primitive and as yet unknown ancestral chordates or possibly even a vertebrate.

Amphioxus, although exhibiting many fundamental chordate features, has an excretory system consisting of segmentally arranged protonephridia with solenocytes such as occur in certain polychaete annelids (Goodrich, 7, 8 and as Minot and Boveri before him knew). These elements are ectodermal in origin and are otherwise only analogous to vertebrate nephrons. How Amphioxus, so vertebrate-like in many other respects, acquired excretory tubules of this sort remains a complete mystery. The mystery deepens in the light of current opinion (e.g. Gregory, 10) which, following a suggestion by Dohrn (6), looks upon Amphioxus as a degenerate derivative of a primitive vertebrate (ostracoderm?) rather than the reverse.

In terms of excretory organs alone, the placing of Amphioxus in a fundamental position as a stem form, would require a return to some kind of scheme deriving the chordates from annelids. Goodrich's proposal in this regard is interesting. He identified vertebrate nephrons with reproductively functioning coelomoducts of annelids. It is true that vertebrate excretory tubules are coelomoducts both morphologically and embryologically, and is also true that certain of them perform genital functions in male vertebrates. By linking those facts with those occasions in annelids where nephridia and genital tubes become united in a common system, one might go far in spinning the web of an argument linking annelids and vertebrates. But an entire generation of morphologists has scrutinized and argued the annelid hypothesis of chordate origin and the contradictions in other organ systems are too profound. It is rather unlikely, therefore, that the annelids as a group and Amphioxus with its as yet unexplained annelid-like excretory system have any relation to or throw any light on the origin of vertebrate nephrons.

Turning to the balanoglossids, one finds an organ, presumably excretory in nature, which has interesting implications. It is associated with that dorsal diverticulum from the digestive tract that runs some distance forward into the basal part of the proboscis. Called the stomochord by certain authors, the diverticulum has been homologized (by Bateson) with the notochord. The soundness of the homology, debated in extenso by a succession of morphologists, is not our concern.

Above and below the stomochord or notochord, as you will, are blood vessels. The dorsal vessel is expanded as a conspicuous sinus from which branch vessels supplying the proboscis and connecting with the ventral vessel. Of principal interest are numerous finger-like projections, or aneurysms, from the dorsal sinus which extend to either side and around the cranial end of the stomochord. The sinus and its aneurysmal derivatives are bounded by the mesothelium of the coelom. Called by Bateson the "proboscis gland", the collection of branching sinuses and associated mesothelium has been termed a "glomerulus" by Spengel (15) and others and excretory functions have been attributed to it. Even though the mesothelium is not organized in the form of tubular nephrons, the makeup of this organ is such as to provide the essential features of a vertebrate excretory organ, namely, a great area of contact between blood and coelomic epithelium. In its simplest form, such as is found in *Protobalanus*, the glomerulus consists of a few symmetrically disposed vascular projections bounded by an undifferentiated epithelium. More commonly, however, the organ is elaborately and complexly branched, the mesothelium considerably specialized, and the whole a surprisingly conspicuous body in the proboscis cavity. Descriptions of such glomeruli, some fairly complete and other superficial, have been given by numerous workers for a variety of species (van der Horst, 11 and Dawydoff, 5). I should like to add to these some observations and comments on the glomerulus of *Ptychodera bahamensis*.

Specimens used in the study were collected some years ago at Tortugas, Florida by Professor Fernandus Payne. Professor Payne kindly turned over this material (stored in alcohol following bouin fixation) to me. Sections, both transverse and sagittal, were cut at thicknesses ranging from 8 to 15 microns. Most were stained by the Azan method, but Ehrlich's hematoxylin, Acid Fuchsin, Orange G-Aniline Blue, and Iron-Hematoxylin were also employed.

The gross form of the glomerulus (Figs. 1, 2 and 3) is that of a narrow, elongate, bilobed mass. Its anteriormost portion abuts the terminal tip of the stomochord with each half lying on either side of the central blood sinus and a partition of connective tissue. Each lobe then extends backward as a tapering arm on either side of the stomochord. Anteriorly the arms of the glomerulus are dorsolateral to the stomochord, but at the level of the broader, irregular base of the chord the arms are strictly dorsal (Fig. 3). Absolute figures may not mean much, but one set of measurements made on a full-grown adult specimen 18 cm. long gives a suggestion of general proportions. The glomerulus in question had a total length of 4.6 mm. The two lobes together in front of the stomochord had a broadest diameter of 0.5 mm.; the greatest diameter of either arm was 0.37 mm.

In describing the general organization of the glomerulus, one hardly knows whether to speak of an elaborately branching and anastomosing network of blood sinuses bounded by mesothelium or an area of intricately folded, branching, blindly-ending mesothelial projections, somewhat akin to a placental villus, within whose maze blood slowly circulates. Perhaps the latter, with its emphasis on the meso-

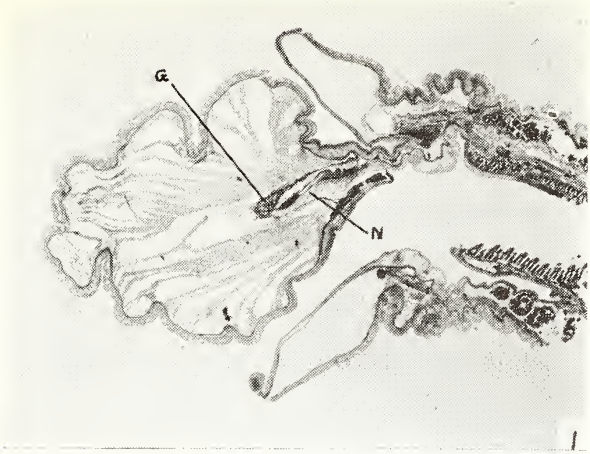

Fig. 1. Longitudinal section through collar and proboscis. x25 G,glomerulus; N,notochord.

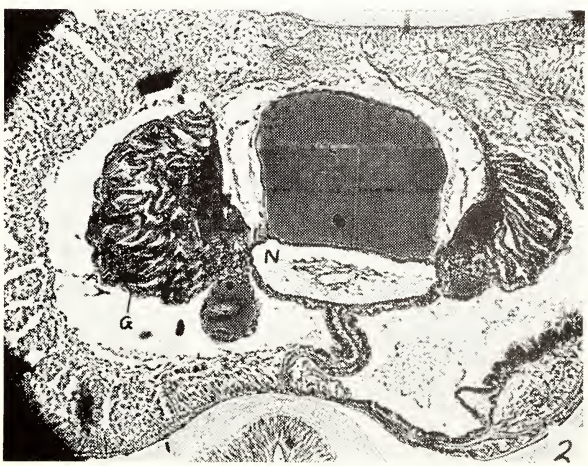

Fig. 2. Transverse section of lobes of glomerulus,G x100 N,notochord; blood sinus in center.

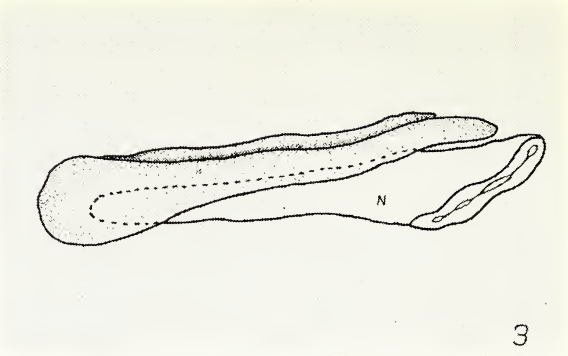

Fig. 3. Diagrammatic reconstruction of glomerulus. N,notochord.

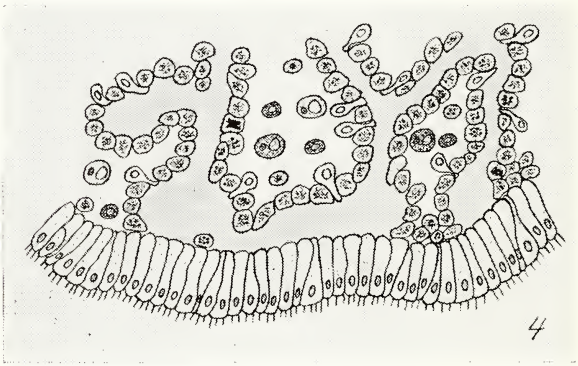

Fig. 4. Semidiagrammatic drawing of portion of glomerulus. x900 Description in text.

Fig. 5. Coelomoduct, C, opening into first gill chamber. x100.

thelium, portrays the situation the better, for the central blood sinus and its aneuryisms are completely devoid of a bounding vascular endothelium. Their walls are only those provided by the coelomic epithelium: the walls of the so-called pericardial cavity and the proboscis coelomic (Fig. 2). This arrangement of coelomic epithelium serving as a vascular wall may possibly anticipate that situation in certain vertebrates wherein the intermediate mesoderm not only provides the nephrons but furnishes cells destined to form the walls of the aorta and cardinal veins. Be that as it may, the important thing in this balanoglossid is the presence of a relatively enormous contact area between vascular liquid and coelomic epithelium. Since the role played by this association presumably is excretory, we should examine its prospects further, i.e., inquire into its capacities with respect to the two principal functions of a vertebrate-type excretory organ: osmoregulation and excretion of nitrogenous waste.

With regard to the former, the following comments are frankly speculative. They are offered here not as conclusions but as a tentative assessment and evaluation of ideas preliminary to any experimental approach which I, or other workers, might some time have the opportunity to make.

We have come to think of the marine invertebrates as being in osmotic equilibrium with the sea and thus facing no problem of water regulation. So it was presumably with the chordate ancester of the vertebrates: its excretory system must have been little concerned, if at all, with water control. Only when the vertebrates ventured into fresh water were they faced with the problem of protection against excessive hydration. Smith (13, 14) has made the interesting suggestion that the armor encasing the early fishes was evolved as a protective water proofing. But this alone was not enough, for the digestive and respiratory systems still afforded routes for the absorption of excessive water; hence the origin of the glomerulus whereby the surplus water could be filtered out and eliminated via the nephrons. Concomitantly, of course, the nephrons became capable of reabsorbing glucose, salts and the like which otherwise would have been lost through the filtration system.

The return of some of the fishes to the sea and the evolution of land forms of course reversed the problem: water conservation rather than elimination became the issue and the glomerulus was a liability rather than an asset. This difficulty appears to have been solved in a number of ways. Nearly all modern marine teleosts show more or less reduction in number and size of the glomeruli, culminating in some which have become completely aglomerular (Grafflin, 9, and Marshall and Smith, 12). They also eliminate large amounts of salt through the gills. The elasmobranchs, on the contrary, employ an entirely different scheme. They have evolved a specialized segment of the nephron which reabsorbs urea and returns it to the blood where it reaches concentrations of as much as 2.0-2.5%. This raises the osmotic pressure of the blood to a level slightly higher than sea water and brings about an inflow of water. Retaining their large glomeruli, marine elasmobranchs

are in effect similar to fresh water teleosts in their technique of osmoregulation, i.e., they take in water and eliminate a hypotonic urine.

Among terrestrial vertebrates we find the problem of water conservation handled somewhat differently. The reptilian-avian line patterns itself after the marine teleosts by reducing the glomerular system, although no completely aglomerular kidney occurs. In the further interest of conservation, water is also reabsorbed via the cloaca plus, in birds, a specialization of a segment of each nephron, the loop of Henle, for water resorption. The last named scheme, tubular resorption, is employed by mammals.

The point of this excursion into the physiological phylogeny of the vertebrate nephros is simply this. If the enteropneusta are, like the marine invertebrates, in osmotic balance with their environment, then the glomerulus must have nothing to do with water control. On the other hand, if the glomerulus is truly vertebrate-like, i.e., is a water filter, then one must search for those physiological conditions tending to bring the animal into osmotic disharmony with the resultant need for such a filter.

Turning now to the other aspect of excretion, the elimination of nitrogenous wastes and other materials, one can, in the absence of physiological data, only see what the structural detail of the glomerulus, meaning the coelomic epithelium, has to offer (Fig. 4). The following description is based on iron-hematoxylin stained material.

The bounding epithelium, that is, that facing the proboscis coelom, is columnar (here and there pseudo-stratified) in type and ciliated (as is the entire coelomic lining). The oval, darkly-staining nuclei, rest distally (at the coelomic ends of the cells) and are arranged so regularly as to give the illusion of a dark stripe traversing the epithelium. The cytoplasm is light in color and rather granular.

As one follows the folds and septa of mesothelium inward, the narrow columnar cells quickly give way to shapes both cuboidal and spherical. Those which flank the blood sinuses are mostly similar in kind, with one exception to be noted. The common type is one cuboidal to round, with highly staining granular cytoplasm and rather obscure nucleus. Such cells are arranged loosely in rows which at one and the same time serve as walls to the blood sinuses and bound the numerous irregular spaces between the equally irregular sinuses. The exceptional cells are occasionally occurring flask-shaped ones (Fig. 4) whose orientation with the neck of the cell attached to the blood sinus suggests the detaching of the cell from its neighbors to become free in the nearby intersinus space.

The intersinus spaces are by no means empty, but contain, on the contrary, a considerable variety of cell forms. In addition to cells similar in size and appearance to those in the flanking walls, at least three other types have been seen (Fig. 4). One is a cell of essentially the same size as those mentioned, but with a very granular and darkly staining cytoplasm and somwhat lighter nucleus. The other two are cells with a diameter half again as large, both with a darkly staining

nucleus and a conspicuous vesicular body. They differ only in that one is somewhat more granular and darker than the other. It should be added that mitotic figures are fairly numerous throughout.

One can only speculate as to the meaning of these cell types. It may very well be they are all variations on one theme, each reflecting differences in physiological state. Furthermore, it is possible they play an excretory role somewhat as follows: cells flanking the blood sinuses pick up waste, detach themselves, and ultimately are swept out of the coelom via the coelomoducts (Fig. 5) which empty into the first gill chamber. Or again we may be dealing with developing phagocytes and an incipient reticulo-endothelial system, not uncommon in conjunction with the excretory system (Torrey, 16). One might also argue for their excretory nature by likening them to similar cells found scattered at random throughout the balanoglossid body, especially among the muscles of the proboscis, and designated nephrocytes by some workers. The one principal point of similarity is the flask-shaped outline of these nephrocytes as they are proliferated from the epithelium bounding the proboscis coelom, later to become spherical and somewhat vesicular bodies among the muscles. But since there is no real evidence that these so-called nephrocytes have an excretory function, it would be unwise to make too much of the similarity.

To sum up and conclude, the glomerulus of Ptychodera morphologically appears to provide all the requisites of an excretory organ of the vertebrate type, to wit, an extensive contact area between blood and coelomic epithelium. In the present state of our knowledge, however, it would be unwise to state unequivocally that it is a kidney and argue therefrom for the vertebrate relationship of the balanoglossids. First, there remains to be answered the question of the need for a water filtering device in an animal presumably in osmotic balance with its environment. Secondly, the whole fabric of the chemistry and physiology of the coelomic epithelium and the cellular derivatives thereof awaits ravelling. In the meantime, the glomerulus can at best be only a weak argument for the vertebrate affinities of the Enteropneusta.

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A New Hymenolepidid Tapeworm from the Fox Sparrow

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A revision of the North American forms of the cestode genus *Aploparaksis* Clerc is in progress; the present paper represents the first step in that work. Actually, the genus has been recorded only twice from North America in the literature (Jones, 4, and Schiller, 7), but there must be a good many manuscript records. At hand are about 400 mounted specimens of eleven species.

I want to thank Dr. Robert Rausch for the loan of the specimens herein reported, and Mr. Joseph L. Hyatt and Mr. John Patchell for assistance in making the drawings.

Aploparaksis passerellae new species

Diagnosis: Characters of the genus. Strobila 24 mm. long, with a maximum width of .8 mm. Longitudinal muscles in two distinct layers, the inner consisting of 24 to 40 large bundles (half dorsal and half ventral), the outer of numerous small bundles. Scolex (Fig. 1, b) 140 to 160 μ wide, including suckers. Prominent rostellum 109 μ in diameter, bearing a single circlet of 25 hooks (Fig. 1, a) 13 μ long. Unarmed suckers 65 to 69 μ in longitudinal diameter. Ventral longitudinal excretory vessels 28 μ in diameter; dorsal longitudinal excretory vessels 5 μ in diameter. Genital pores unilateral on right side; genital ducts passing laterally dorsal to both longitudinal excretory vessels.

Testis aporal, 100 to 120 μ in breadth (Fig. 1, d); a slender vas deferens leading from testis to a large, ovoid, medially-placed external seminal vesicle; tapering cirrus pouch 190 to 220 μ long by 30 μ in maximum diameter in mature segments, reaching almost to mid-line of segment; cirrus stout, not spined.

Slender vagina (Fig. 1, c) anterior to cirrus pouch; small, ovoid seminal receptacle antero-poral to midpoint of segment, 30 to 40 μ in breadth, leading by a short duct to the Mehlis gland; trianguloid Mehlis gland immediately posterior to midpoint of segment, 50 μ in breadth; ovoid vitelline gland, 60 μ in breadth, immediately ventral to Mehlis gland. Early uterus not seen; later uterus saccate, finally filling most of segment; ellipsoid eggs without polar thicknesses, 24 to 26 by 26 to 30 μ; ellipsoid onchospheres 17 to 21 by 19 to 24 μ.

Host: Fox Sparrow, *Passerella iliaca iliaca.*

Location: Intestine.

Locality: Madison, Wisconsin.

Type: Whole mount, U. S. Nat. Mus. Helm. Coll. No. 37365.

Material: This description is based upon two specimens collected, stained, and mounted by Robert Rausch. One specimen was stained with

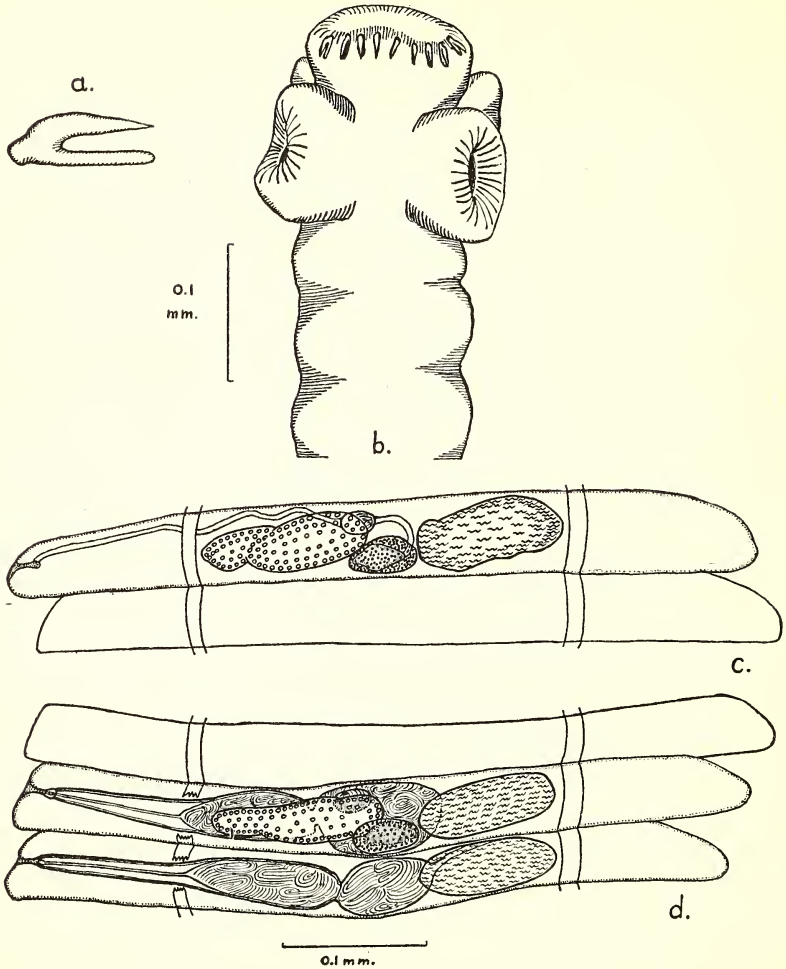

Fig. 1. All drawings are of *Aploparaksis passercllae*, new species. All except *a* were drawn with the aid of a micro-projector.

a. Rostellar hook, free hand drawing.

b. Scolex

c. Mature segment, ventral view; includes female genital system plus testis only. Note that the Mehlis gland is dorsal to the vitelline gland. Reconstructed from serial sections.

d. Two mature segments, ventral view. In the upper segment all genital structures except some small ducts are included; the lower segment includes the male genital system, only. Reconstructed from serial sections.

carmine and mounted whole in balsam; the other was sectioned. Most of the genital organs were studied in a series of horizontal sections.

Discussion: The only species of *Aploparaksis* previously well described from passeriform birds is *A. dujardinii* (Krabbe 6) (Clerc, 1), from thrushes and starlings in Europe (Fuhrmann, 2, 3). *A. dujardinii* differs from *A. passerellae* in possessing more and larger hooks and a more slender cirrus pouch. The present species may easily be differentiated from all other members of the genus except *dujardinii* by means of its larger number of hooks and larger rostellum. (See key in Schiller, 7). Kintner (5) pointed out that *A. fringillarum* of von Linstrow, (8) (*nec Hymenolepsis f. Rudolphi*) was probably a species of *Aploparaksis*, which he named *A. linstowi.* The form described by von Linstrow (8), however, had only ten hooks of a shape very different from those of *A. passerellae* and *A. dujardinii.*

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INDIANA JUNIOR ACADEMY OF SCIENCE

Officers for 1951:

President: DAVID THOMAS, Junior Academy, Elkhart High School, Elkhart.

Vice-President: JUDITH SHEPHERD, Camera Club, Sullivan High School, Sullivan.

Secretary: MARILYN SWIFT, Science Club, Valparaiso High School, Valparaiso.

Members of the Council: DARL F. WOOD, Mishawaka, (1947-1951); EVELYN WAGONER, Elkhart, (1948-1952); MAX FORSYTH, Indianapolis, (1949-1953); HAROLD STEWART, Bloomington, (1950-1954); ARTHUR L. SMITH, South Bend, (1951-1955).

PROGRAM OF THE NINETEENTH ANNUAL MEETING

November 3, 1951

Jordan Hall, Room 131
Butler University, Indianapolis, Indiana

9:00-10:00 a.m. Exhibits, Jordan Hall, Room 126

10:00 a.m. Morning Session, Room 131, Jordan Hall

General Session, David Thomas, presiding

Reading of the minutes of the 1950 meeting, Marilyn Swift, Secretary.

Greetings, Dr. John E. Potzger, Professor of Botany, Butler University.

1. The Relation of Metabolism to Body Temperature in Working Men (Illustrated). Bill Robinson, Science Club, University High School, Bloomington.

2. Chemical Processes in Testing Milk. Don Chapmon, Science Club, Mishawaka High School, Mishawaka.

3. A Summertime Project in Hydroponics. Russell Noyes, Science Club, University High School, Bloomington.

4. Hereditary Characteristics in Poultry. Harry Krueckeberg, Nature Study Club, Technical High School, Indianapolis.

5. Reptiles. Wilbur Mitchell, Biology Club, Lew Wallace High School, Gary.

6. Correct Methods of Collecting Rocks. Arnold Larson, National Scientific Honor Society, Bloomington High School, Bloomington.

7. Inter-planetary Travel (Demonstration). Arnold Larson and Joe Mosier, National Scientific Honor Society, Bloomington High School, Bloomington.

12:00 Noon Luncheon

1:30 p.m. Afternoon Session, Jordan Hall, Room 131

Business session

8. Pre-historic Animals. Fred Walter, Biology Club, Lew Wallace High School, Gary.

9. The Raising of Moth Larvae. John Cordill, Science Club, Thomas Carr Howe High School, Indianapolis.

10. Analysis of Water for the Presence of Escherichia coli. Ward Thayer, Science Club, Thomas Carr Howe High School, Indianapolis.

11. Seedlings from an Historic Oak, *Quercus bicolor,* Junior Izaak Walton Club, Central High School, South Bend.

12. Tests for Bacterial Count on Raw and Pasteurized Milk, Junior Academy, Central High School, South Bend.

Election Results. David Thomas, President.

"Best boy" and "Best girl" science awards. Darl F. Wood.

MINUTES AND REPORT OF THE INDIANA JUNIOR ACADEMY OF SCIENCE

The nineteenth annual meeting of the Indiana Junior Academy of Science was held Saturday, November 3, 1951 in room 131 of Jordan Hall, Butler University, Indianapolis, Indiana.

The exhibit room opened at 8:00 a.m. in the chemistry laboratory, room 126, in Jordan Hall. Numerous scientific projects and demonstrations were displayed by club members.

The general session was called to order by president David Thomas, Junior Academy, Elkhart High School, Elkhart. The president introduced the state officers, vice-president, Judith Shepherd, Camera Club, Sullivan High School, Sullivan, and secretary, Marilyn Swift, Science Club, Valparaiso High School, Valparaiso.

The minutes of the 1950 meeting were read by the secretary. Dr. John E. Potzger, Department of Botany, Butler University, welcomed the members of the Junior Academy and encouraged them to maintain their interest in science.

A series of very interesting and informative papers were read by members of the high school science clubs who participated in the program. The titles indicated that members engaged in a wide range of activity in both the physical and biological sciences. Approximately one hundred and fifty students, teachers and guests attended the meeting.

The afternoon business session was conducted apart from the main assembly program. A new system of voting by delegates was tried for the first time. Each high school represented was allowed two delegates.

The following officers were elected for 1952: President, David Brenner, Biology Club, New Castle High School, New Castle; Vice-president, Joyce Baldwin, Phy-Chem Club, Elmhurst High School, Fort Wayne; Secretary, Nancy Miller, Junior Academy, Elkhart High Echool, Elkhart.

A new office of press secretary was established to work with the press secretary of the Senior Academy to give the Junior Academy the advantages of better publicity. David Taylor, Thomas Carr Howe High School, Indianapolis, was elected to the office.

Mr. Charles E. Karst, co-sponsor, Science Club, Mishawaka, was elected as a new council member to succeed Mr. Darl F. Wood. Mr. Karst teaches chemistry at the Mishawaka High School.

Mr. David Thomas, Elkhart, president of the Junior Academy for 1951 was chosen to receive the annual title of "best boy". There were no candidates for the "best girl" award. Recipients of this honor are given a year's membership in the American Association for the Advancement of Science.

Professor Howard H. Michaud, Department of Forestry, Purdue University, urged the clubs to begin planning for next year's meeting. He pointed out that the success of the Junior Academy depends upon a continuous program of activity and interest in science and that the annual meeting is but the culmination of the year's work. Professor Michaud is State Sponsor of the Junior Academy.

New Clubs added during the past year include the Junior Academy of Clayton High School, and the Science Club of Bedford High School. Mr. Howard Lewis is sponsor of the Clayton Club and Mr. Robert Carpenter is sponsor of the Bedford Club. The Science Club, New Albany High School, was re-instated last spring with Mr. L. S. Rose, Head of the Science Department, acting as sponsor.

Approximately thirty-five high school science clubs are affiliated with the Indiana Junior Academy of Science. The number of active clubs has doubled in the past five years. It is believed that many other high schools of Indiana would benefit through participation in the work of the Junior Academy.

INDIANA JUNIOR ACADEMY OF SCIENCE CLUBS

Name and School	Date Organized	Sponsor
Anderson Science	1936	B. B. Horton
Attica Sci-Math	1949	J. Claude Daugherty
Bedford Science	1951	Robert E. Carpenter

Bloomington		
National Scientific Honor Society, Bloomington H.S.	1931	Harold Stewart
Science, University H.S.	1938	P. L. Whitaker E. Wayne Gross
Clayton		
Junior Academy	1951	Howard C. Lewis
Crawfordsville		
Up-N-Atom	1950	David Wells
Elkhart		
Junior Academy	1940	Evelyn Wagoner
Fort Wayne		
Nature, Central H.S.	1940	Iva Spangler
Phy-Chem, Elmhurst H.S.	1935	Ruth Wimmer
Nature, North Side H.S.	1936	Vesta Thompson
Gary		
Beaker Breakers, Edison H.S.	1947	Mrs. Martha B. Connor
Biology, Lew Wallace H.S.	1935	Lola Lemon
Biology, William A. Wirt H.S.	1945	Mrs. Frances Huddleston
Future Scientists of America, Tolleston School	1949	Juanita Joice
Klub Kem Klub, Lew Wallace H.S.	1941	Mrs. Helen McKenzie
Gas City		
Science	1936	Roy McKee
Hammond		
Science, Morton Jr. H.S.	1949	Faye E. Moorman
Huntingsburg		
Science	1949	Wilmer K. Pellett
Indianapolis		
Nature, Shortridge H.S.	1947	Max Forsyth
Nature, Technical H.S.	1932	Howard L. Cook
Science, Howe H.S.	1949	Jerry Motley
Science, Shortridge H.S.	1931	Mrs. Henrietta A. Parker
Science, Washington H.S.	1937	Estil Van Dorn
Lafayette		
Science, Centennial School	1948	Henriette S. Ball
Lowell		
Science	1948	Robert J. Brannock
Marion		
Science	1936	Keith Stroup
Mishawaka		
Science	1936	Darl F. Wood Charles E. Karst

New Albany		
Science	1951	L. S. Rose
New Castle		
Science	1947	Robert Rinehart
Richmond		
Science, Senior H.S.	1950	Kathryn Coulter Elma Eliason
South Bend		
Central Junior-Senior Science, Central H.S.	1939	
A. Junior Izaak Walton		A. L. Smith
B. Chemistry Club		F. S. Sanford
Sullivan		
Camera	1939	Ruth Hinkle
Terre Haute		
Laboratory School Science, Laboratory School	1939	Russell McDougal
Valparaiso		
Sciemus	1931	Gerald Doeden

INSTRUCTIONS FOR CONTRIBUTORS

Eligibility

Papers

Indiana Academy of Science members in good standing are eligible to submit papers for publication in the Proceedings. When a paper is signed by two or several authors, all must be members in good standing. Preferably, eligibility should be established before submitting the paper, as such papers are given priority. In any case, all authors must be certified by the Treasurer for payment of dues and old reprint bills at the time of the deadline (see below). Papers reaching the editor after the deadline are ineligible. All papers must be accompanied by an abstract in the form specified below, marked "for the editor".

Abstracts

If the Divisional Chairman puts a paper on his program for the Fall Meeting, the abstract will be printed in the Proceedings regardless of the author's membership status, unless the full paper is published.

Time and procedure for Submitting Abstracts: One typed **original** of each abstract, marked "for the editor" may be submitted to the Divisional Chairman before the meeting or the author may mail it direct to the editor. This should be ready for publication with a minimum of editing, i.e., in the standard abstract form (see a Proceedings abstract) and double spaced; it should not include directions to the chairman regarding time, lantern, etc. The latter information may be added to a copy marked "for the Divisional Chairman" and sent to him. The editor cannot accept carbon copies of abstracts or papers. The length of an abstract should not exceed 200 words. Items A, B, C, E, F, and O (below) apply generally to abstracts as well as papers.

Deadline at Editorial Office

Whether sent *via* the Divisional Chairman as prescribed, or directly, all material for the Proceedings must reach the editor within 20 days following the Fall Meeting.

Preparation of Manuscripts

A. **Refer to Volume 61 of the Proceedings for the accepted style of abstracts and papers, and follow this, especially in literature citations, headings, and footnotes.**

B. Type on 11 x 8½ inch bond paper with a new ribbon, leaving ample margins. **Double-space everything**, including title, authors' names and institutions, footnotes, quotations, legends and literature list. The original will become the printer's copy; if it must be retyped it will be sent back to the author for this.

C. Footnotes should be kept to an absolute minimum. Necessary footnotes should be numbered consecutively throughout; asterisks are not used. Acknowledgments may be placed only in the introduction or in a footnote. If your abstract must cite literature, use a footnote.

D. LITERATURE CITATIONS in a paper should not occur in footnotes, but in an **alphabetized** list at the end of the paper, **headed "Literature Cited".** The highly abbreviated form used by chemists has **not** been adopted for the Proceedings. Follow this model:

7. Doe, J. B., and R. C. Roe. 1949. New light from old radioactive carbon. Jour. Am. Biological Soc. **34**:273-305.

E. Only initial letters of the words in titles, headings, and table headings should be capitalized.

F. Do not underline anything except scientific names, in headings or elsewhere.

G. All literature listed, and all tables and illustrations should be **referred to** in the text.

H. Tables, which are very expensive to print, should be reduced to a minimum. Avoid small tables scattered through the text. Each table should be typed on a separate letter-size sheet.

I. New authors, especially, are reminded that a scientific paper should summarize the work, not recapitulate it. It must be very much more concise than a university thesis, avoiding all unnecessary material, especially long tables and lists of little interest except to the author.

J. Major professors are urged to **review** all papers by their graduate students, for both form and content, before they are sent in for publication. Of those based upon university theses, manuscripts carrying a pencilled O. K. and signature by the professor will be given preference over those without such indication of review.

K. Photographs should be printed on glossy paper, and have good contrast. It is best to mount them trimmed to fit tightly together at the edges, in groups on stiff cardboard with rubber cement. Proportion the group for a full page of the Proceedings, or use the full width of the page (4⅛") and any part of the page's height. Do not mix line drawings and photographs in the same group. Legends should be on a separate letter-size sheet, numbered to correspond.

L. The originals for line drawings should be no more than 2 or 3 times the diameter desired for the printed figure. The lettering should be very carefully done, and of suitable size to allow for the necessary reduction. Do not submit printed maps when the necessary reduction will efface the narrower lines or render some of the lettering hardly legible; such maps should be redrawn and lettered in adequate size letters, omitting unnecessary details. It is suggested that the total of illustrations and tables not exceed 20 per cent of the length of the whole paper.

M. The summary should be complete and clear in itself, and not over 4 per cent of the length of the paper. For very short papers no summary is necessary.

N. Reprints of papers are paid for by authors, at cost. They are ordered at the time the author returns the corrected galley proof to the editor. Abstracts are not reprinted.

O. The editor needs, at the time he mails out galley in March, **current addresses** for all coauthors of all abstracts and papers. Many former graduate students lose the opportunity to order reprints when mail addressed to them is returned for lack of forwarding addresses. It is suggested that the student's permanent home address be written on the reverse side of that abstract copy marked "for the editor."

Selection of Papers

Every year a few more papers are submitted than can be published with the available funds. Therefore, not all papers received can be included in the Proceedings. Manuscripts prepared concisely, in the style recommended above, will receive first consideration. Authors should not expect to publish very long papers in the Proceedings. Among papers of primarily regional interest, e.g., in certain aspects of botany, zoology, geology, geography, and anthropology, those dealing with Indiana material will be accorded preference.

The selection of papers for the Proceedings is the responsibility of the Editorial Committee.

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of the

INDIANA ACADEMY OF SCIENCE

CUMULATIVE INDEX

Volumes 51-60

1941-1950

Compiled

by

RAY C. FRIESNER

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